

*The*  
CHEMISTS'  
YEAR BOOK  
1925

B.  
FOL

THE UNIVERSITY  
OF ILLINOIS  
LIBRARY

540.5  
Cy

1925

cop. 2

REMOTE STORAGE

~~CERAMICS~~

~~DEPARTMENT~~

The Fi  
Trade l  
a very  
compou  
fields c  
pharma  
reliable

ve  
ise  
nic  
he  
gy,  
he  
als

and Analytical Reagents has led to their  
adoption wherever the highest value is placed on  
scientific accuracy.

*A copy of our latest Catalogue will be  
supplied on application.*

**THE BRITISH DRUG HOUSES, Ltd.**

Makers of Fine Chemicals.

GRAHAM STREET, CITY ROAD, LONDON, N. 1.  
CHEMICAL WORKS: WHARF RD., LONDON, N. 1.



# Tables annuelles de Constantes

*Published under the Patronage of  
The International Union of Pure and Applied Chemistry.*

---

Containing numerical data relating to Chemistry,  
Physics and Technology, collected from all  
journals published since 1910.

---

Volume I. For the Year 1910, 728 pp. ;  
published 1912.

Volume II. For the Year 1911, 760 pp. ;  
published 1913.

Volume III. For the Year 1912, 596 pp. ;  
published 1914.

The above volumes are not sold separately.

Net Price of the above Volumes :

60 francs ; 80 francs, bound, each volume.

Volume IV. For the Years 1913 to 1916 inclusive,  
in two parts.

Net Price of Volume IV. :

210 francs ; 250 francs bound.

---

Volume V. (in preparation).

For the Years 1917 to 1922 inclusive.

---

All enquiries regarding subscriptions for Volume V.  
should be addressed to :

Dr. C. MARIE,  
General Secretary of the Committee,  
9, RUE DE BAGNEUX, PARIS (6<sup>e</sup>)

# INSTITUTE OF CHEMISTRY

OF GREAT BRITAIN AND IRELAND.

---

Founded 1877. Incorporated by Royal Charter, 1885.

---

EXAMINATIONS for the Associateship and Fellowship are held in January, April and September. Application forms may be obtained from the Registrar. Other particulars will be forwarded to Candidates whose applications are accepted by the Council, and who intend to present themselves.

---

REGULATIONS for the admission of Students, Associates and Fellows: Gratis.

---

APPOINTMENTS REGISTER.—A Register of Chemists who are available for appointments is kept at the office of the Institute. The facilities afforded by this Register are available to Companies and Firms requiring the services of Analytical, Research, and Works Chemists, and to Universities, Colleges, Technical Schools, &c., requiring Teachers of Chemistry and Technology.

---

All communications to be addressed to **THE REGISTRAR**, The Institute of Chemistry, 30, Russell Square, London, W.C. 1.

CHEMISTS' YEAR BOOK  
OF THE  
AMERICAN CHEMICAL SOCIETY

# The Chemists' Year Book

1925

FRANCIS M. SEAR





THE  
CHEMISTS'  
YEAR BOOK

1925

EDITED BY  
**F. W. ATTACK**

*M.Sc. Tech., D.Sc. (Manc.), B.Sc. (Lond.),  
Fellow of the Institute of Chemistry.*

ASSISTED BY  
**L. WHINYATES, A.M.C.T., A.I.C.**

*American data in collaboration with*  
**FRANCIS M. TURNER, Jr.**  
*Technical Editor, The Chemical Catalog Company, Inc.*

Manchester, England :  
**SHERATT & HUGHES**  
34, Cross Street.

New York, U.S.A. : **THE CHEMICAL CATALOG COMPANY, INC.,**  
19, East 24th Street.

Toronto, Canada : **THE WESTMAN PRESS LIMITED,**  
57, Queen Street West.

THE  
CHEMISTS'  
YEAR BOOK

EDITED BY  
H. W. ATACK

NEW YORK: J. B. LIPPINCOTT COMPANY, 1907.

FRANCIS M. TURNER, JR.  
LONDON: THE CHEMICAL CATALOGUE COMPANY, LTD.

[Made and printed in Great Britain]



540.5

CY

1925

cop-2

## REMOTE STORAGE

## PREFACE TO THE TENTH EDITION (1925).

In presenting the Tenth Edition of the Year Book, the Editor wishes to thank all those who have assisted throughout a decade in enabling this volume to be revised and published annually. It would have been impossible to do this without very thorough co-operation.

Every attempt has been made to adopt all suggestions for revision and to maintain the standard of publication without unduly extending the scope.

The policy of placing the Year Book in one volume has met with general approval, and a further slight revision of arrangement which seemed desirable has been made this year.

The main revision this year has been the complete rewriting and extension of the tables giving "General Properties of Organic Compounds," for which special thanks are due to Dr. E. Hope.

THE EDITOR.

34, Cross Street,  
Manchester.

December, 1924

Kingston, Ontario,  
Canada.

574142

Ceramics 16 my 25 Stock. 1925 (ed. 10) Cont. 11 June 25 Harding



# CONTENTS.

---

|  | Page |
|--|------|
| <b>Atomic Weights, 1925</b> . . . . .                      | 1    |
| Multiples of the Atomic Weights . . . . .                  | 3    |
| Formula Weights of Certain Radicals . . . . .              | 7    |
| Periodic System of Mendeleeff . . . . .                    | 8    |
| <b>Physico-Chemical Constants</b> . . . . .                | 10   |
| Physical Constants of the Elements . . . . .               | 11   |
| Physical Constants of Alloys . . . . .                     | 13   |
| Specific Heats . . . . .                                   | 15   |
| Viscosity . . . . .  | 19   |
| Refractive Indices . . . . .                               | 22   |
| Cryoscopic and Ebullioscopic Constants . . . . .           | 23   |
| Density and Specific Gravity . . . . .                     | 24   |
| Specific Gravities of Solutions . . . . .                  | 37   |
| Universal Dilution Table . . . . .                         | 108  |
| Densities of Gases . . . . .                               | 109  |
| Solubilities . . . . .                                     | 117  |
| Correction of Gas Volumes . . . . .                        | 158  |
| Correction of Barometer Readings . . . . .                 | 171  |
| Vapour Pressures . . . . .                                 | 173  |
| Correction of Thermometer Readings . . . . .               | 181  |
| Correction of Boiling Points . . . . .                     | 183  |
| <b>Crystallography</b> . . . . .                           | 189  |
| <b>Properties of Minerals</b> . . . . .                    | 200  |
| <b>General Properties of Inorganic Compounds</b> . . . . . | 262  |
| <b>Nomenclature of Organic Compounds</b> . . . . .         | 330  |
| <b>General Properties of Organic Compounds</b> . . . . .   | 334  |
| <b>Qualitative Analysis</b> . . . . .                      | 518  |
| Dry-way Tests . . . . .                                    | 518  |
| Solution Analysis . . . . .                                | 527  |
| Notes on Group Separations . . . . .                       | 558  |
| Examination of Insoluble Substances . . . . .              | 564  |
| Examination of an Alloy . . . . .                          | 566  |
| Reactions of Certain of the "Rarer" Metals . . . . .       | 567  |



|  | Page |
|--|------|
| <b>Reagents</b> - - - - -                                  | 572  |
| Impurities of Reagents - - - - -                           | 574  |
| <b>Volumetric Analysis</b> - - - - -                       | 584  |
| Standard Solutions - - - - -                               | 585  |
| Neutralisation Methods - - - - -                           | 586  |
| Oxidation methods. Iodimetry - - - - -                     | 587  |
| Titanous chloride and Methylene blue - - - - -             | 590  |
| Precipitation Methods - - - - -                            | 594  |
| <b>Factors for Quantitative Analysis</b> . - - - -         | 596  |
| <b>Gas Analysis</b> - - - - -                              | 604  |
| <b>Ultimate Organic Analysis</b> - - - - -                 | 621  |
| <b>Electro-Chemical Analysis</b> - - - - -                 | 622  |
| <b>Spectrum Analysis</b> - - - - -                         | 634  |
| <b>Water Analysis</b> - - - - -                            | 638  |
| <b>Fuels and Illuminants</b> - - - - -                     | 652  |
| <b>Analysis of Clays, Firebricks, and Silica Materials</b> | 680  |
| <b>Analysis of Portland Cement</b> - - - - -               | 692  |
| <b>Acid and Alkali Manufacture</b> - - - - -               | 699  |
| <b>Oils and Fats</b> - - - - -                             | 719  |
| <b>Essential Oils</b> - - - - -                            | 748  |
| <b>Paints and Pigments</b> - - - - -                       | 776  |
| <b>Agricultural Chemistry</b> - - - - -                    | 798  |
| <b>Dairy Products</b> - - - - -                            | 827  |
| <b>Carbohydrates</b> . - - - - -                           | 853  |
| <b>Brewing Materials</b> - - - - -                         | 890  |
| <b>Wort and Beer</b> - - - - -                             | 912  |
| <b>Spirits</b> - - - - -                                   | 922  |
| <b>Tannin Materials</b> - - - - -                          | 934  |
| <b>Leather Analysis</b> - - - - -                          | 943  |
| <b>Cellulose and Paper</b> - - - - -                       | 946  |
| <b>Textile Fibres</b> - - - - -                            | 955  |
| <b>Coal Tar</b> - - - - -                                  | 957  |
| <b>Intermediate Products</b> - - - - -                     | 973  |
| <b>Composition of Synthetic Dyestuffs</b> - - - -          | 980  |

|  | Page |
|--|------|
| <b>Identification of Dyestuffs</b> - - - - -         | 1009 |
| <b>Physiological Chemistry</b> - - - - -             | 1030 |
| <b>Alkaloids</b> - - - - -                           | 1048 |
| <b>Pharmaceutical Names of Synthetic Chemistry</b> - | 1073 |
| <b>Trade Names of Drugs</b> - - - - -                | 1078 |
| <b>Glossary of Certain Medical Terms</b> - - -       | 1085 |
| <b>Indiarubber</b> - - - - -                         | 1086 |
| <b>Tobacco</b> - - - - -                             | 1103 |
| <b>Chemical Invention and the Law of Patents</b> -   | 1108 |
| <b>Notable Dates in the History of Chemistry</b> -   | 1113 |
| <b>Chemical and other Scientific Journals</b> - -    | 1120 |
| <b>Conversion Tables for Weights and Measures</b> -  | 1124 |
| <b>Conversion of Thermometric Scales</b> - - -       | 1129 |
| <b>Conversion of Barometer Readings</b> - - -        | 1133 |
| <b>Hydrometric Tables</b> - - - - -                  | 1134 |
| <b>Five-Figure Logarithms</b> - - - - -              | 1137 |
| <b>Mathematical Constants</b> - - - - -              | 1159 |
| Powers of Numbers - - - - -                          | 1160 |
| Natural Sines and Tangents - - - - -                 | 1162 |
| Mensuration Formulæ - - - - -                        | 1164 |
| <b>Mechanical Constants</b> - - - - -                | 1165 |
| <b>Memoranda</b> - - - - -                           | 1166 |
| <b>Index</b> - - - - -                               |      |





The Chemists' Year Book  
1925



# ATOMIC WEIGHTS 1925.

| Name.                               | Symbol. | O = 16. |
|-------------------------------------|---------|---------|
| Aluminium .....                     | Al      | 27.0    |
| Antimony .....                      | Sb      | 120.2   |
| Argon .....                         | A       | 39.9    |
| Arsenic .....                       | As      | 74.96   |
| Barium .....                        | Ba      | 137.37  |
| Bismuth .....                       | Bi      | 209.0   |
| Boron .....                         | B       | 10.9    |
| Bromine .....                       | Br      | 79.92   |
| Cadmium .....                       | Cd      | 112.40  |
| Cæsium .....                        | Cs      | 132.81  |
| Calcium .....                       | Ca      | 40.07   |
| Carbon .....                        | C       | 12.005  |
| Cerium .....                        | Ce      | 140.25  |
| Chlorine .....                      | Cl      | 35.46   |
| Chromium .....                      | Cr      | 52.0    |
| Cobalt .....                        | Co      | 58.97   |
| Columbium ( <i>Niobium</i> ) .....  | Cb      | 93.1    |
| Copper .....                        | Cu      | 63.57   |
| Dysprosium .....                    | Dy      | 162.5   |
| Erbium .....                        | Er      | 167.7   |
| Europium .....                      | Eu      | 152.0   |
| Fluorine .....                      | F       | 19.0    |
| Gadolinium .....                    | Gd      | 157.3   |
| Gallium .....                       | Ga      | 70.1    |
| Germanium .....                     | Ge      | 72.5    |
| Glucinum ( <i>Beryllium</i> ) ..... | Gl      | 9.1     |
| Gold .....                          | Au      | 197.2   |
| Helium .....                        | He      | 4.00    |
| Holmium .....                       | Ho      | 163.5   |
| Hydrogen .....                      | H       | 1.008   |
| Indium .....                        | In      | 114.8   |
| Iodine .....                        | I       | 126.92  |
| Iridium .....                       | Ir      | 193.1   |
| Iron .....                          | Fe      | 55.84   |
| Krypton .....                       | Kr      | 82.92   |
| Lanthanum .....                     | La      | 139.0   |
| Lead .....                          | Pb      | 207.20  |
| Lithium ....                        | Li      | 6.94    |
| Lutetium .....                      | Lu      | 175.0   |
| Magnesium .....                     | Mg      | 24.32   |
| Manganeses .....                    | Mn      | 54.93   |

| Name.                       | Symbol. | O = 16 |
|-----------------------------|---------|--------|
| Mercury .....               | Hg      | 200.6  |
| Molybdenum .....            | Mo      | 96.0   |
| Neodymium .....             | Nd      | 144.3  |
| Neon .....                  | Ne      | 20.2   |
| Nickel .....                | Ni      | 58.68  |
| Niton (radium emanation)... | Nt      | 222.4  |
| Nitrogen .....              | N       | 14.008 |
| Osmium .....                | Os      | 190.9  |
| Oxygen .....                | O       | 16.00  |
| Palladium .....             | Pd      | 106.7  |
| Phosphorus .....            | P       | 31.04  |
| Platinum .....              | Pt      | 195.2  |
| Potassium .....             | K       | 39.10  |
| Praseodymium .....          | Pr      | 140.9  |
| Radium .....                | Ra      | 226.0  |
| Rhodium .....               | Rh      | 102.9  |
| Rubidium .....              | Rb      | 85.45  |
| Ruthenium .....             | Ru      | 101.7  |
| Samarium .....              | Sa      | 150.4  |
| Scandium .....              | Sc      | 45.1   |
| Selenium .....              | Se      | 79.2   |
| Silicon .....               | Si      | 28.1   |
| Silver .....                | Ag      | 107.88 |
| Sodium .....                | Na      | 23.00  |
| Strontium .....             | Sr      | 87.63  |
| Sulphur .....               | S       | 32.06  |
| Tantalum .....              | Ta      | 181.5  |
| Tellurium .....             | Te      | 127.5  |
| Terbium .....               | Tb      | 159.2  |
| Thallium .....              | Tl      | 204.0  |
| Thorium .....               | Th      | 232.15 |
| Thulium .....               | Tm      | 169.9  |
| Tin .....                   | Sn      | 118.7  |
| Titanium .....              | Ti      | 48.1   |
| Tungsten .....              | W       | 184.0  |
| Uranium .....               | U       | 238.2  |
| Vanadium .....              | V       | 51.0   |
| Xenon .....                 | X       | 130.2  |
| Ytterbium .....             | Yb      | 173.5  |
| Yttrium .....               | Yt      | 89.33  |
| Zinc .....                  | Zn      | 65.37  |
| Zirconium .....             | Zr      | 90.6   |

# Multiples of the Atomic Weights and their Logarithms.

(Calculated from Atomic Weights, 1923.)

|           | 1       | 2      | 3      | 4      | 5      | 6      | 7      | 8       | 9       | 10      | Log.    |
|-----------|---------|--------|--------|--------|--------|--------|--------|---------|---------|---------|---------|
| Aluminium | 0.00000 | .30103 | .47712 | .60206 | .69897 | .77815 | .84510 | .90309  | .95424  | 1.00000 |         |
| Antimony  | 27.0    | 54.0   | 81.0   | 108.0  | 135.0  | 162.0  | 189.0  | 216.0   | 243.0   | 270     | 1.43136 |
| Arsenic   | 120.2   | 240.4  | 360.6  | 480.8  | 601    | 721.2  | 841.4  | 961.6   | 1081.8  | 1202    | 2.07990 |
| Barium    | 74.96   | 149.92 | 224.88 | 299.84 | 374.8  | 449.76 | 524.72 | 599.58  | 674.64  | 749.6   | 1.87483 |
| Bismuth   | 137.37  | 274.74 | 412.11 | 549.48 | 686.85 | 824.22 | 961.59 | 1098.96 | 1236.33 | 1373.7  | 2.13789 |
| Boron     | 209     | 418    | 627    | 836    | 1045   | 1254   | 1463   | 1672    | 1881    | 2090    | 2.32015 |
| Bromine   | 10.9    | 21.8   | 32.7   | 43.6   | 54.5   | 65.4   | 76.3   | 87.2    | 98.1    | 109     | 1.03743 |
| Cadmium   | 79.92   | 159.84 | 239.76 | 319.68 | 399.6  | 479.52 | 559.44 | 639.36  | 719.28  | 799.2   | 1.90266 |
| Cæsium    | 112.4   | 224.8  | 337.2  | 449.6  | 562    | 674.4  | 786.8  | 899.2   | 1011.6  | 1124    | 2.05077 |
| Calcium   | 132.81  | 265.62 | 398.43 | 531.24 | 664.05 | 796.86 | 929.67 | 1062.48 | 1195.29 | 1328.1  | 2.12323 |
| Carbon    | 40.07   | 80.14  | 120.21 | 160.28 | 200.35 | 240.42 | 280.49 | 320.56  | 360.63  | 400.7   | 1.60282 |
| Cerium    | 12.005  | 24.010 | 36.015 | 48.020 | 60.025 | 72.030 | 84.035 | 96.040  | 108.045 | 120.05  | 1.07936 |
| Chlorine  | 140.25  | 280.5  | 420.75 | 561    | 701.25 | 841.5  | 981.75 | 1122    | 1262.25 | 1402.5  | 2.14690 |
| Chromium  | 35.46   | 70.92  | 106.38 | 141.84 | 177.30 | 212.76 | 248.22 | 283.68  | 319.14  | 354.6   | 1.54974 |
| Cobalt    | 52      | 104    | 156    | 208    | 260    | 312    | 364    | 416     | 468     | 520     | 1.71600 |
| Columbium | 58.97   | 117.94 | 176.91 | 235.88 | 294.85 | 353.82 | 412.79 | 471.76  | 530.73  | 589.7   | 1.77063 |
| Copper    | 93.1    | 186.2  | 279.3  | 372.4  | 465.5  | 558.6  | 651.7  | 744.8   | 837.9   | 931.0   | 1.96895 |
| Erbium    | 63.57   | 127.14 | 190.71 | 254.28 | 317.85 | 381.42 | 444.99 | 508.56  | 572.13  | 635.7   | 1.80325 |
| Fluorine  | 167.7   | 335.4  | 503.1  | 670.8  | 838.5  | 1006.2 | 1173.9 | 1341.6  | 1509.3  | 1677    | 1.22453 |
| Gallium   | 19      | 38     | 57     | 76     | 95     | 114    | 133    | 152     | 171     | 190     | 1.27875 |
| Germanium | 70.1    | 140.2  | 210.3  | 280.4  | 350.5  | 420.6  | 490.7  | 560.8   | 630.9   | 701     | 1.84572 |
|           | 72.5    | 145    | 217.5  | 290    | 362.5  | 435    | 507.5  | 580     | 652.5   | 725     | 1.86034 |

|            | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8       | 9       | Σ      | Log.    |
|------------|--------|--------|--------|--------|--------|--------|--------|---------|---------|--------|---------|
| Glucinum   | 9.1    | 18.2   | 27.3   | 36.4   | 45.5   | 54.6   | 63.7   | 72.8    | 81.9    | 91.0   | 0.95904 |
| Gold       | 197.2  | 394.4  | 591.6  | 788.8  | 986    | 1183.2 | 1380.4 | 1577.6  | 1774.8  | 1972   | 2.29491 |
| Hydrogen   | 1.008  | 2.016  | 3.024  | 4.032  | 5.04   | 6.048  | 7.056  | 8.064   | 9.072   | 10.08  | 0.00346 |
| Indium     | 114.8  | 229.6  | 344.4  | 459.2  | 574    | 688.8  | 803.6  | 918.4   | 1033.2  | 1148   | 2.05994 |
| Iodine     | 126.92 | 253.84 | 380.76 | 507.68 | 634.6  | 761.52 | 888.44 | 1015.36 | 1142.28 | 1269.2 | 2.10353 |
| Iridium    | 193.1  | 386.2  | 579.3  | 772.4  | 965.5  | 1158.6 | 1351.7 | 1544.8  | 1737.9  | 1931   | 2.28578 |
| Iron       | 55.84  | 111.68 | 167.52 | 223.36 | 279.2  | 335.04 | 390.88 | 446.72  | 502.56  | 558.4  | 1.74695 |
| Lanthanum  | 139    | 278    | 417    | 556    | 695    | 834    | 973    | 1112    | 1251    | 1390   | 2.14301 |
| Lead       | 207.2  | 414.4  | 621.6  | 828.8  | 1036.0 | 1243.2 | 1450.4 | 1657.6  | 1864.8  | 2072   | 2.31639 |
| Lithium    | 6.94   | 13.88  | 20.82  | 27.76  | 34.7   | 41.64  | 48.58  | 55.52   | 62.46   | 69.4   | 0.84136 |
| Magnesium  | 24.32  | 48.64  | 72.96  | 97.28  | 121.6  | 145.92 | 170.24 | 194.56  | 218.88  | 243.2  | 1.38596 |
| Manganese  | 54.93  | 109.86 | 164.79 | 219.72 | 274.65 | 329.58 | 384.51 | 439.44  | 494.37  | 549.3  | 1.73981 |
| Mercury    | 200.6  | 401.2  | 601.8  | 802.4  | 1003   | 1203.6 | 1404.2 | 1604.8  | 1805.4  | 2006   | 2.30233 |
| Molybdenum | 96     | 192    | 288    | 384    | 480    | 576    | 672    | 768     | 864     | 960    | 1.98227 |
| Nickel     | 58.68  | 117.36 | 176.04 | 234.72 | 293.4  | 352.08 | 410.76 | 469.44  | 528.12  | 586.8  | 1.76849 |
| Nitrogen   | 14.008 | 28.016 | 42.024 | 56.032 | 70.040 | 84.048 | 98.056 | 112.064 | 126.072 | 140.08 | 1.14638 |
| Osmium     | 190.9  | 381.8  | 572.7  | 763.6  | 954.5  | 1145.4 | 1336.3 | 1527.2  | 1718.1  | 1909   | 2.28081 |
| Oxygen     | 16     | 32     | 48     | 64     | 80     | 96     | 112    | 128     | 144     | 160    | 1.20412 |
| Palladium  | 106.7  | 213.4  | 320.1  | 426.8  | 533.5  | 640.2  | 746.9  | 853.6   | 960.3   | 1067   | 2.02816 |
| Phosphorus | 31.04  | 62.08  | 93.12  | 124.16 | 155.20 | 186.24 | 217.28 | 248.32  | 279.36  | 310.4  | 1.49192 |
| Platinum   | 195.2  | 390.4  | 585.6  | 780.8  | 976    | 1171.2 | 1366.4 | 1561.6  | 1756.8  | 1952   | 2.29048 |
| Potassium  | 39.1   | 78.2   | 117.3  | 166.4  | 195.5  | 234.6  | 273.7  | 312.8   | 351.9   | 391    | 1.59218 |
| Rhodium    | 102.9  | 205.8  | 308.7  | 411.6  | 514.5  | 617.4  | 720.3  | 823.2   | 926.1   | 1029   | 2.01242 |



|                     | 1      | 2      | 3      | 4      | 5      | 6       | 7       | 8       | 9       | 10      | Log.   |         |
|---------------------|--------|--------|--------|--------|--------|---------|---------|---------|---------|---------|--------|---------|
| 0.00000             | .30103 | .47712 | .60206 | .69837 | .77815 | .84510  | .90309  | .95424  | 1.00000 |         |        |         |
| Rubidium . . . . .  | Rb     | 85.45  | 170.9  | 256.35 | 341.8  | 427.25  | 512.7   | 598.15  | 683.6   | 769.05  | 854.5  | 1.93171 |
| Ruthenium . . . . . | Ru     | 101.7  | 203.4  | 305.1  | 406.8  | 508.5   | 610.2   | 711.9   | 813.6   | 915.3   | 1017   | 2.00732 |
| Samarium . . . . .  | Sa     | 150.4  | 300.8  | 451.2  | 601.6  | 752     | 902.4   | 1052.8  | 1203.2  | 1353.6  | 1504   | 2.17725 |
| Scandium . . . . .  | Sc     | 45.1   | 90.2   | 135.3  | 180.4  | 225.5   | 264.6   | 308.7   | 352.8   | 396.9   | 451    | 1.65418 |
| Selenium . . . . .  | Se     | 79.2   | 158.4  | 237.6  | 316.8  | 396     | 481.2   | 561.4   | 641.6   | 721.8   | 792    | 1.89873 |
| Silicon . . . . .   | Si     | 28.1   | 56.2   | 84.3   | 112.4  | 140.5   | 168.6   | 196.7   | 224.8   | 252.9   | 281    | 1.44871 |
| Silver . . . . .    | Ag     | 107.83 | 215.76 | 323.64 | 431.52 | 539.4   | 647.28  | 755.16  | 863.04  | 970.92  | 1078.8 | 2.03294 |
| Sodium . . . . .    | Na     | 23     | 46     | 69     | 92     | 115     | 138     | 161     | 184     | 207     | 230    | 1.36173 |
| Strontium . . . . . | Sr     | 87.63  | 175.26 | 262.89 | 350.52 | 438.15  | 525.78  | 613.41  | 701.04  | 788.67  | 876.3  | 1.94265 |
| Sulphur . . . . .   | S      | 32.06  | 64.12  | 96.18  | 128.24 | 160.30  | 192.36  | 224.42  | 256.48  | 288.54  | 320.6  | 1.50596 |
| Tantalum . . . . .  | Ta     | 181.5  | 363    | 544.5  | 726    | 907.5   | 1089    | 1270.5  | 1452    | 1633.5  | 1815   | 2.25888 |
| Tellurium . . . . . | Te     | 127.5  | 255    | 382.5  | 510    | 637.5   | 765     | 892.5   | 1020    | 1147.5  | 1275   | 2.10551 |
| Thallium . . . . .  | Tl     | 204    | 408    | 612    | 816    | 1020    | 1224    | 1428    | 1632    | 1836    | 2040   | 2.30963 |
| Thorium . . . . .   | Th     | 232.15 | 464.30 | 696.45 | 928.60 | 1160.75 | 1392.90 | 1625.05 | 1857.20 | 2089.35 | 2321.5 | 2.36577 |
| Tin . . . . .       | Sn     | 118.7  | 237.4  | 356.1  | 474.8  | 593.5   | 712.2   | 830.9   | 949.6   | 1068.3  | 1187   | 2.07445 |
| Titanium . . . . .  | Ti     | 48.1   | 96.2   | 144.3  | 192.4  | 240.5   | 288.6   | 336.7   | 384.8   | 432.9   | 481    | 1.68215 |
| Tungsten . . . . .  | W      | 184    | 368    | 552    | 736    | 920     | 1104    | 1288    | 1472    | 1656    | 1840   | 2.26482 |
| Uranium . . . . .   | U      | 238.2  | 476.4  | 714.6  | 952.8  | 1191.0  | 1429.2  | 1667.4  | 1905.6  | 2143.8  | 2382   | 2.37694 |
| Vanadium . . . . .  | V      | 51     | 102    | 153    | 204    | 255     | 306     | 357     | 408     | 459     | 510    | 1.70757 |
| Ytterbium . . . . . | Yb     | 173.5  | 347    | 520.5  | 694    | 867.5   | 1041    | 1214.5  | 1388    | 1561.5  | 1735   | 2.23930 |
| Yttrium . . . . .   | Y      | 89.33  | 173.66 | 267.99 | 357.32 | 446.65  | 535.98  | 625.31  | 714.64  | 803.97  | 893.3  | 1.95085 |
| Zinc . . . . .      | Zn     | 65.37  | 130.74 | 196.11 | 261.48 | 326.85  | 392.22  | 457.59  | 522.96  | 588.33  | 653.7  | 1.81538 |
| Zirconium . . . . . | Zr     | 90.6   | 181.2  | 271.8  | 362.4  | 453     | 543.6   | 634.2   | 724.8   | 815.4   | 906    | 1.95713 |

|                | 11        | 12      | 13      | 14      | 15      | 16      | 17      | 18      | 19      | 20     | Log.    |
|----------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|--------|---------|
| 1.04139        | 1.07918   | 1.11394 | 1.14613 | 1.17609 | 1.20412 | 1.23045 | 1.25527 | 1.27875 | 1.30103 |        |         |
| Carbon .....   | C 132.055 | 144.060 | 156.065 | 168.070 | 180.075 | 192.080 | 204.085 | 216.090 | 228.095 | 240.10 | 1.07936 |
| Chlorine ..... | Cl 390.06 | 425.52  | 460.98  | 496.44  | 531.90  | 567.36  | 602.82  | 638.28  | 673.74  | 709.20 | 1.54974 |
| Hydrogen ..... | H 11.088  | 12.096  | 13.104  | 14.112  | 15.12   | 16.128  | 17.136  | 18.144  | 19.152  | 20.16  | 0.00346 |
| Nitrogen ..... | N 154.088 | 168.096 | 182.104 | 196.112 | 210.120 | 224.128 | 238.136 | 252.144 | 266.152 | 280.16 | 1.14638 |
| Oxygen .....   | O 176     | 192     | 208     | 224     | 240     | 256     | 272     | 288     | 304     | 320    | 1.20412 |
| Silicon .....  | Si 309.1  | 337.2   | 365.3   | 393.4   | 421.5   | 449.6   | 477.7   | 505.8   | 533.9   | 562    | 1.44871 |
| 21             | 22        | 23      | 24      | 25      | 26      | 27      | 28      | 29      | 30      |        |         |
| 1.32222        | 1.34242   | 1.36173 | 1.38021 | 1.39794 | 1.41497 | 1.43136 | 1.44716 | 1.46240 | 1.47712 |        | Log.    |
| Carbon .....   | C 252.105 | 264.110 | 276.115 | 288.120 | 300.125 | 312.130 | 324.135 | 336.140 | 348.145 | 360.15 | 1.07936 |
| Hydrogen ..... | H 21.168  | 22.176  | 23.184  | 24.192  | 25.2    | 26.208  | 27.216  | 28.224  | 29.232  | 30.24  | 0.00346 |
| Oxygen .....   | O 336     | 352     | 368     | 384     | 400     | 416     | 432     | 448     | 464     | 480    | 1.20412 |
| 31             | 32        | 33      | 34      | 35      | 36      | 37      | 38      | 39      | 40      |        |         |
| 1.49136        | 1.50515   | 1.51851 | 1.53148 | 1.54407 | 1.55630 | 1.56820 | 1.57978 | 1.59106 | 1.60206 |        | Log.    |
| Carbon .....   | C 372.155 | 384.160 | 396.165 | 408.170 | 420.175 | 432.180 | 444.185 | 456.190 | 468.195 | 480.20 | 1.07936 |
| Hydrogen ..... | H 31.248  | 32.256  | 33.264  | 34.272  | 35.28   | 36.288  | 37.296  | 38.304  | 39.312  | 40.32  | 0.00346 |
| 41             | 42        | 43      | 44      | 45      | 46      | 47      | 48      | 49      | 50      |        |         |
| 1.61278        | 1.62325   | 1.63347 | 1.64345 | 1.65321 | 1.66276 | 1.67210 | 1.68124 | 1.69020 | 1.69897 |        | Log.    |
| Carbon .....   | C 492.205 | 504.210 | 516.215 | 528.220 | 540.225 | 552.230 | 564.235 | 576.240 | 588.245 | 600.25 | 1.07936 |
| Hydrogen ..... | H 41.328  | 42.336  | 43.344  | 44.352  | 45.36   | 46.368  | 47.376  | 48.384  | 49.392  | 50.4   | 0.00346 |

# Formula Weights of Certain Radicals and their Multiples.

| Radical       | Formula                   | 1       | 2      | 3      | 4      | 5      | 6       | 7       | 8       | 9       | 10      | Log.    |
|---------------|---------------------------|---------|--------|--------|--------|--------|---------|---------|---------|---------|---------|---------|
| Amino         | ..... $\text{NH}_2$       | 0.00000 | .30103 | .47712 | .60206 | .69897 | .77815  | .84510  | .90309  | .95424  | 1.00000 |         |
| Ammonium...   | $\text{NH}_4$             | 16.024  | 32.048 | 48.072 | 64.096 | 80.120 | 96.144  | 112.168 | 128.192 | 144.216 | 160.240 | 1.20477 |
| Ammonium...   | $\text{NH}_4$             | 18.040  | 36.080 | 54.120 | 72.160 | 90.200 | 108.240 | 126.280 | 144.320 | 162.360 | 180.400 | 1.25624 |
| Carbonate ..  | $\text{CO}_3$             | 60.00   | 120.00 | 180.00 | 240.00 | 300.00 | 360.00  | 420.00  | 480.00  | 540.00  | 600.00  | 1.77815 |
| Carbonyl .... | $\text{CO}$               | 28.00   | 56.00  | 84.00  | 112.00 | 140.00 | 168.00  | 196.00  | 224.00  | 252.00  | 280.00  | 1.44716 |
| Carboxyl ..   | $\text{COOH}$             | 45.01   | 90.02  | 135.02 | 180.03 | 225.04 | 270.05  | 315.06  | 360.06  | 405.07  | 450.08  | 1.65331 |
| Ethyl .....   | $\text{C}_2\text{H}_5$    | 29.04   | 58.08  | 87.12  | 116.16 | 145.20 | 174.24  | 203.28  | 232.32  | 261.36  | 290.40  | 1.46300 |
| Hydroxyl ..   | $\text{OH}$               | 17.01   | 34.02  | 51.02  | 68.03  | 85.04  | 102.05  | 119.06  | 136.06  | 153.07  | 170.08  | 1.23065 |
| Methyl ....   | $\text{CH}_3$             | 15.02   | 30.05  | 45.07  | 60.10  | 75.12  | 90.14   | 105.17  | 120.19  | 135.22  | 150.24  | 1.17679 |
| Naphthyl ..   | $\text{C}_{10}\text{H}_7$ | 127.06  | 254.11 | 381.17 | 508.22 | 635.28 | 762.34  | 889.39  | 1016.45 | 1143.50 | 1270.56 | 2.10399 |
| Nitrate ....  | $\text{NO}_3$             | 62.01   | 124.02 | 186.02 | 248.03 | 310.04 | 372.05  | 434.06  | 496.06  | 558.07  | 620.08  | 1.79245 |
| Nitro .....   | $\text{NO}_2$             | 46.01   | 92.02  | 138.02 | 184.03 | 230.04 | 276.05  | 322.06  | 368.06  | 414.07  | 460.08  | 1.66284 |
| Phenyl ....   | $\text{C}_6\text{H}_5$    | 77.04   | 154.08 | 231.12 | 308.16 | 385.20 | 462.24  | 539.28  | 616.32  | 693.36  | 770.40  | 1.88672 |
| Phenylene ..  | $\text{C}_6\text{H}_4$    | 76.03   | 152.06 | 228.10 | 304.13 | 380.16 | 456.19  | 532.22  | 608.26  | 684.29  | 760.32  | 1.88099 |
| Sulphate ..   | $\text{SO}_4$             | 96.06   | 192.12 | 288.18 | 384.24 | 480.30 | 576.36  | 672.42  | 768.48  | 864.54  | 960.60  | 1.98254 |
| Sulphonic ..  | $\text{SO}_3\text{H}$     | 81.07   | 162.14 | 243.20 | 324.27 | 405.34 | 486.40  | 567.48  | 648.54  | 729.61  | 810.68  | 1.90886 |
| Water .....   | $\text{H}_2\text{O}$      | 18.02   | 36.03  | 54.05  | 72.06  | 90.08  | 108.10  | 126.11  | 144.13  | 162.14  | 180.16  | 1.25565 |

# Periodic System of Mendeleeff.

| Group                       | O.         | I.          | II.         | III.                          | IV.             | V.                            | VI.             | VII.                          | VIII.                                     |
|-----------------------------|------------|-------------|-------------|-------------------------------|-----------------|-------------------------------|-----------------|-------------------------------|---|
| Volatile Hydrogen compounds |            |             |             |                               | MH <sub>4</sub> | MH <sub>3</sub>               | MH <sub>2</sub> | MH                            |   |
| Highest salt-forming oxides |            | M O         | MO          | M <sub>2</sub> O <sub>3</sub> | MO <sub>2</sub> | M <sub>2</sub> O <sub>5</sub> | MO <sub>3</sub> | M <sub>2</sub> O <sub>7</sub> | MO <sub>4</sub>                           |
| Series 1                    |            | H<br>1·008  |             |                               |                 |                               |                 |                               |   |
| 2                           | He<br>4·00 | Li<br>6·94  | Gl<br>9·1   | B<br>10·9                     | C<br>12·005     | N<br>14·008                   | O<br>16·00      | F<br>19·0                     |   |
| 3                           | Ne<br>20·2 | Na<br>23·00 | Mg<br>24·32 | Al<br>27·0                    | Si<br>28·1      | P<br>31·04                    | S<br>32·06      | Cl<br>35·46                   |   |
| 4                           | A<br>39·9  | K<br>39·10  | Ca<br>40·07 | Sc<br>45·1                    | Ti<br>48·1      | V<br>51·0                     | Cr<br>52·0      | Mn<br>54·93                   | Fe<br>55·84<br>Co<br>58·97<br>Ni<br>58·68 |
| 5                           |            | Cu<br>63·57 | Zn<br>65·37 | Ga<br>70·1                    | Ge<br>72·5      | As<br>74·96                   | Se<br>79·2      | Br<br>79·92                   |   |

| Series 6 | Kr<br>82.92 | Rb<br>85.45  | Sr<br>87.63  | Yt<br>89.33 | Zr<br>90.6   | Clb<br>93.1 | Mo<br>96.0  | —           | Rn<br>101.7 | Rh<br>102.9 | Pd<br>106.7 |
|----------|-------------|--------------|--------------|-------------|--------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 7        |             | Ag<br>107.88 | Cd<br>112.40 | In<br>114.8 | Sn<br>118.7  | Sb<br>120.2 | Te<br>127.5 | I<br>126.92 |             |             |             |
| 8        | Xe<br>130.2 | Cs<br>132.81 | Ba<br>137.37 | La<br>139.0 | Ce<br>140.25 | —           | —           | —           | —           | —           | —           |
| 9        |             | —            | —            | —           | —            | —           | —           | —           |             |             |             |
| 10       | —           | —            | —            | —           | —            | Ta<br>181.5 | W<br>184.0  | —           | Os<br>190.9 | Ir<br>193.1 | Pt<br>195.2 |
| 11       |             | Au<br>197.2  | Hg<br>200.6  | Tl<br>204.0 | Pb<br>207.20 | Bi<br>209.0 | —           | —           |             |             |             |
| 12       | Nt<br>222.4 | —            | Ra<br>226.0  | —           | Th<br>232.15 | —           | U<br>238.2  | —           | —           | —           | —           |
| Group    | O.          | I.           | II.          | III.        | IV.          | V.          | VI.         | VII.        | VIII.       |             |             |

## PHYSICO-CHEMICAL CONSTANTS.

G. BARR, D.Sc., VERNEY STOTT, B.A., and EDITH G. WILSON, Sc.B

Thermal Constants of Elements. (After J. Mills, *Physical Chem.*, 1917).

The specific heats are the true specific heats at the temperature stated, not interval values unless an interval is given. The figures for gases are at constant volume. Specific heats and latent heats are in calories per gram. Values in italics are for modifications not mentioned by Mills; a few melting points have also been added.

| Element.                    | at 0°C.               | Specific heat.   |         | Melting point. °C. | Latent heat |         | Boiling point. °C. |
|-----------------------------|-----------------------|------------------|---------|--------------------|-------------|---------|--------------------|
|                             |                       | solid.           | liquid. |                    | at m.p.     | at b.p. |                    |
| Aluminium .....             | ·208                  | ·319             | ·308    | 658°               | 82·0        | 1771°   | 1800°              |
| Antimony .....              | ·0486                 | ·0608            | —       | 630°               | 40·2        | —       | 1440°              |
| Argon .....                 | ·0747 (0°—2500°C.)    | —                | —       | -188°              | —           | 38·8    | -185·8             |
| Arsenic, <i>cryst.</i> .... | ·0794                 | —                | —       | 815°               | —           | —       | 616°               |
| <i>amorph.</i> ..           | ·076 (21°—65°C.)      | —                | —       | —                  | —           | —       | —                  |
| Barium .....                | ·05 (room temp.)      | —                | —       | 850°               | —           | —       | —                  |
| Beryllium .....             | ·376                  | —                | —       | 1279°              | 277°        | —       | —                  |
| Bismuth .....               | ·0301                 | 0316             | ·0363   | 271°               | 12·39       | 198·9   | 1420°              |
| Boron, <i>cryst.</i> ....   | ·217                  | —                | —       | 2200°              | —           | —       | —                  |
| <i>amorph.</i> ..           | ·307 (0°—100°C.)      | —                | —       | —                  | —           | —       | —                  |
| Bromine .....               | —                     | ·106             | ·107    | -7·4               | 16·18       | 46·0    | 63·1               |
| Cadmium .....               | ·0548                 | ·0622            | —       | 320·9              | 13·7        | 209·7   | 765·9              |
| Caesium .....               | ·0522                 | ·0600            | 0595    | 28·5               | 3·76        | —       | 670°               |
| Calcium .....               | ·152                  | —                | —       | 803°               | —           | —       | —                  |
| Carbon, graphite ..         | ·156                  | ·817             | —       | 3600°              | —           | 12033°  | 3600°              |
| diamond ..                  | ·103 (·460 at 100°C.) | —                | —       | —                  | —           | —       | —                  |
| charcoal ..                 | ·165 (0°—24°C.)       | ·238 (0°—224°C.) | —       | —                  | —           | —       | —                  |
| Cerium .....                | ·045 (0°—100°C.)      | —                | —       | 623°               | —           | —       | —                  |
| Chlorine gas .....          | ·0806                 | —                | —       | —                  | —           | —       | —                  |
| liquid ....                 | ·226                  | ·170             | ·212    | -103·6             | 22·96       | 69·2    | -33·7              |
| Chromium .....              | ·104                  | —                | —       | 1550°              | —           | —       | 2200°              |
| Cobalt .....                | ·099                  | —                | —       | 1478°              | —           | —       | —                  |
| Copper .....                | ·092                  | —                | —       | 1083°              | 47·7        | 1104°   | 2310°              |



| Element.            | at 0°C.               | Specific heat.<br>solid. | at m.p.           | liquid. | Melting<br>point.<br>°C. | Latent heat<br>of fusion<br>at m.p. | Latent heat<br>of vaporisation<br>at b.p. | Boiling<br>point.<br>°C. |
|---------------------|-----------------------|--------------------------|-------------------|---------|--------------------------|-------------------------------------|---|--------------------------|
| Gallium .....       | ·079 (12°–23°C.)      | —                        | ·080 (13°–112°C.) | —       | 13·5                     | 19·1                                | —   | —                        |
| Germanium .....     | ·0737 (0°–100°C.)     | —                        | —                 | —       | 900·9                    | —                                   | —   | —                        |
| Gold .....          | ·0392                 | ·0349                    | —                 | —       | 1062·                    | 16·3                                | 395·5                                     | 2200·                    |
| Helium .....        | ·756 (–15° to 150°C.) | —                        | —                 | —       | —                        | —                                   | 4·9?                                      | 268·7                    |
| Hydrogen .....      | 2·39                  | —                        | —                 | 3·4     | –259·                    | 16·0                                | 108·6                                     | –252·7                   |
| Indium .....        | ·057 (0°–100°C.)      | —                        | —                 | —       | 155·                     | —                                   | —   | —                        |
| Iodine .....        | ·0514                 | ·0570                    | —                 | ·108    | 113·5                    | 11·71                               | 23·95                                     | 184·35                   |
| Iridium .....       | ·0312                 | ·0485?                   | —                 | —       | 2290·                    | —                                   | 932·                                      | —                        |
| Iron .....          | ·104                  | ·167                     | —                 | —       | 1530·                    | 69·0                                | —   | 2450·                    |
| Krypton .....       | —                     | —                        | —                 | —       | –169·                    | —                                   | 27·5                                      | –151·7                   |
| Lanthanum .....     | ·045 (0°–100°C.)      | —                        | —                 | —       | 810·                     | —                                   | —   | —                        |
| Lead .....          | ·0303                 | ·0339                    | —                 | ·0406   | 327·4                    | 5·35                                | 211·0                                     | 1525·                    |
| Lithium .....       | ·800                  | 1·169                    | —                 | —       | 180·                     | 32·81                               | —   | >1400·                   |
| Magnesium .....     | ·238                  | ·298                     | —                 | ·374    | 650·                     | 72·0                                | 1933·                                     | 1120·                    |
| Manganese .....     | ·107                  | —                        | —                 | —       | 1260·                    | —                                   | —   | 1900·                    |
| Mercury .....       | ·0337                 | ·0332                    | —                 | ·0339   | –38·9                    | 2·785                               | 67·8                                      | 356·95                   |
| Molybdenum .....    | ·0683                 | —                        | —                 | —       | 2535·                    | —                                   | —   | —                        |
| Neon .....          | —                     | —                        | —                 | —       | —                        | —                                   | —   | –239·                    |
| Nickel .....        | ·103                  | —                        | —                 | —       | 1452·                    | —                                   | —   | 2400·                    |
| Nitrogen .....      | ·165                  | —                        | —                 | ·476    | –210·5                   | 13·7                                | 47·75                                     | –195·7                   |
| Osmium .....        | ·0311 (19°–98°C.)     | —                        | —                 | —       | 2200·                    | —                                   | —   | —                        |
| Oxygen .....        | ·154                  | —                        | —                 | ·347    | –235·                    | 5·7?                                | 50·92                                     | –182·8                   |
| Palladium .....     | ·058                  | ·0835                    | —                 | —       | 1549·                    | 36·3                                | 947·                                      | —                        |
| Phosphorus, red ... | ·160                  | —                        | —                 | —       | —                        | —                                   | —   | —                        |
| yellow              | ·175                  | ·186                     | —                 | ·204    | 44·                      | 5·02                                | 130·4                                     | 289                      |

| Element.              | at 0°C.                  | Specific heat.<br>solid. | at m.p. | liquid. | Melting<br>point.<br>°C. | Latent heat<br>of fusion<br>at m.p. | Latent heat<br>of vaporisation<br>at b.p. | Boiling<br>point.<br>°C. |
|-----------------------|--------------------------|--------------------------|---------|---------|--------------------------|-------------------------------------|---|--------------------------|
| Platinum .....        | ·0310                    | ·0418                    | —       | —       | 1755·                    | 27·18                               | 650·6                                     | —                        |
| Potassium .....       | ·1729                    | ·1914                    | ·1844   | —       | 63·5                     | 14·63                               | —   | 762·2                    |
| Rhodium .....         | ·0580 (10°—97°C.)        | —                        | —       | —       | 1907·                    | —                                   | —   | —                        |
| Rubidium .....        | ·0802                    | ·0919                    | ·0911   | —       | 39·0                     | 6·15                                | —   | 696·                     |
| Ruthenium .....       | ·061 (0°—100°C.)         | —                        | —       | —       | 1900·P                   | —                                   | —   | —                        |
| Selenium, cryst. ...  | ·079                     | ·105                     | —       | —       | 217·                     | —                                   | —   | 688·                     |
| Selenium, amorph. ... | ·095 (18°—38°C.)         | —                        | —       | —       | —                        | —                                   | —   | —                        |
| Silicon, cryst. ....  | ·160                     | —                        | —       | —       | 1414·                    | —                                   | —   | —                        |
| Silver .....          | ·0556                    | ·0730                    | ·0748   | —       | 961·                     | 24·72                               | 531·0                                     | 1955·                    |
| Sodium .....          | ·284                     | ·329                     | ·323    | —       | 97·9                     | 27·37                               | —   | 882·9                    |
| Strontium .....       | ·074 (P temp. near room) | —                        | —       | —       | 900·                     | —                                   | —   | —                        |
| Sulphur, rhombic      | ·166                     | ·185                     | ·228    | —       | 110·2                    | 15·32                               | —   | —                        |
| monoclinic            | ·174                     | ·199                     | ·228    | —       | 114·6                    | 11·96                               | 339·9                                     | 444·5                    |
| Tantalum .....        | ·0331                    | —                        | —       | —       | 2850·                    | —                                   | —   | —                        |
| Tellurium, cryst. ... | ·0477                    | ·0519                    | —       | —       | 451·                     | —                                   | —   | 1390·                    |
| Thallium .....        | ·0309                    | ·0338                    | —       | —       | 302·                     | 7·2                                 | —   | 1280·                    |
| Thorium .....         | ·028 (0°—100°C.)         | —                        | —       | —       | 1690·                    | —                                   | —   | —                        |
| Tin, white .....      | ·0536                    | ·0657                    | ·0637   | —       | 231·8                    | 14·23                               | 597·1                                     | 2275·                    |
| Titanium .....        | ·0985                    | —                        | —       | —       | 1795·                    | —                                   | —   | —                        |
| Tungsten .....        | ·0321                    | —                        | —       | —       | 3267·                    | —                                   | —   | —                        |
| Uranium .....         | ·028 (0°—99°C.)          | —                        | —       | —       | —                        | —                                   | —   | —                        |
| Vanadium .....        | ·124 (17°—99°C.)         | —                        | —       | —       | 1720·                    | —                                   | —   | —                        |
| Xenon .....           | —                        | —                        | —       | —       | -140·                    | —                                   | 23·8                                      | -10·                     |
| Zinc .....            | ·0921                    | ·1033                    | ·0956   | —       | 419·                     | 27·45                               | 417·6                                     | 918·                     |
| Zirconium .....       | ·067 (0°—100°C.)         | —                        | —       | —       | 1300·P                   | —                                   | —   | —                        |

## Other Physical Constants of Elements and of Alloys.

Coefficient of linear expansion  $\alpha$  in equation  $l_t = l_o (1 + \alpha t)$ . The values given are approximate (varying with previous history of the metal) and for temperatures about 20°C.

Thermal conductivities and specific electrical resistances of metals are mostly for drawn wire. The specific electric resistance is the resistance in ohms of 1 cm. length of wire 1 sq. cm. in cross-section. If the  $10^6$  in the heading is replaced by  $10^2$  the figures give the resistance per metre of wire 1 sq. mm. in section.

| <i>Element.</i>          | Coeff. of<br>linear<br>expansion<br>$\alpha \times 10^6$ . | Thermal<br>conductivity.<br><i>k</i> . | Specific<br>electrical<br>resistance<br>$\times 10^6$ . |
|--------------------------|--|--|---|
| Aluminium .....          | 25.5   | .504                                   | 2.95  |
| Antimony .....           | 11.5   | .044                                   | 40.5  |
| Bismuth .....            | 15.7   | .019                                   | 119.  |
| Cadmium .....            | 30.7   | .222                                   | 7.5   |
| Calcium .....            | —  | —                                      | 4.6   |
| Carbon, gas carbon ..... | 5.4  | .010                                   | 5000.   |
| graphite .....           | 7.9  | .012                                   | 3000.   |
| diamond .....            | 1.2  | —                                      | —   |
| Cobalt .....             | 12.4   | —                                      | 9.0   |
| Copper .....             | 16.7   | .918                                   | 1.78  |
| Gold .....               | 14.2   | .700                                   | 2.42  |
| Iridium .....            | 6.5  | —                                      | 5.3   |
| Iron, pure .....         | 11.8   | .161                                   | 9.8   |
| wrought .....            | 11.9   | .144                                   | 13.9  |
| cast .....               | 10.4   | .12 - .15                              | —   |
| steel (0.1% C.) .....    | 11.  | .11                                    | 20.   |
| Lead .....               | 28.  | .083                                   | 20.8  |
| Lithium .....            | —  | —                                      | 8.9   |
| Magnesium .....          | 26.  | .376                                   | 4.3   |
| Mercury .....            | $\frac{1}{3} \times 18.2$                                  | .020                                   | 94.1 (0°C.)   |
| Molybdenum .....         | —  | —                                      | 4.1   |
| Nickel .....             | 12.8   | .142                                   | 11.8  |
| Osmium .....             | 6.6  | —                                      | 9.5   |
| Palladium .....          | 11.7   | .168                                   | 10.7  |
| Platinum .....           | 8.9  | .166                                   | 11.0  |
| Potassium .....          | 71.  | —                                      | 6.6   |
| Rhodium .....            | —  | —                                      | 6.  |
| Selenium .....           | 36.8   | —                                      | $2 \times 10^{22}$                                      |
| Silver .....             | 19.0   | 1.00                                   | 1.66  |
| Sodium .....             | 61.  | .36                                    | 4.8   |

| <i>Element or Alloy.</i>    | $\alpha \times 10^6$ . | <i>k.</i> | <i>Sp. Re. <math>\times 10^6</math>.</i> |
|-----------------------------|------------------------|-----------|--|
| Sulphur .....               | 66                     | —         | $7 \times 10^{21}$                       |
| Tantalum .....              | 8                      | —         | 14.6                                     |
| Tellurium .....             | 34                     | —         | 21                                       |
| Thallium .....              | 30.2                   | —         | 17.6                                     |
| Tin .....                   | 22.0                   | .155      | 11.3                                     |
| Tungsten .....              | 4.4                    | —         | 5.0                                      |
| Zinc .....                  | 26.0                   | .265      | 6.1                                      |
| Brass 66% Cu .....          | 17.8                   | .29       | 5.5                                      |
| Bronze 12% Sn .....         | 23.0                   | —         | 18                                       |
| Constantan 40% Ni .....     | 14.5                   | .054      | 49                                       |
| German silver .....         | 18                     | .07       | 30                                       |
| Invar 36% Ni .....          | 0.9                    | —         | 75                                       |
| Manganin 12% Mn, 4% Ni ..   | —                      | .053      | 42                                       |
| Platin-iridium 10% Ir ..... | 8.7                    | —         | 24                                       |
| Solder 33% Sn .....         | 25                     | —         | 17                                       |

## Melting Points of Alloys of Low Melting Point.

(K. Heine, 1906.)

| M.P.<br>°C. | Percentage composition by weight. |      |      |      | Alloy.                             |
|-------------|-----------------------------------|------|------|------|------------------------------------|
|             | Pb.                               | Sn.  | Bi.  | Cd.  |                                    |
| 60—68       | 26.7                              | 13.3 | 50.0 | 10.0 | Lipowitz.                          |
| 65.5        | 25.0                              | 12.5 | 50.0 | 12.5 | Wood                               |
| 67.5        | 25.2                              | 14.1 | 51.1 | 9.6  | „                                  |
| 68.5        | 25.9                              | 14.5 | 52.5 | 7.0  | Newton.                            |
| 75.5        | 25.0                              | 14.2 | 50.7 | 10.1 | Lipowitz.                          |
| 80.0        | 21.4                              | 21.4 | 57.1 | —    | D'Arcet.                           |
| 90.0        | 35.0                              | 29.9 | 35.1 | —    | Rose.                              |
| 91.6        | 30.0                              | 20.0 | 50.0 | —    | Lichtenberg                        |
| 91.6        | 32.7                              | 12.4 | 54.8 | —    | „                                  |
| 93.         | 25.0                              | 25.0 | 50.0 | —    | Rose                               |
| 93.7        | 27.9                              | 15.9 | 56.2 | —    | „                                  |
| 94.         | 42.1                              | 15.8 | 42.1 | —    | „                                  |
| 94.         | 27.5                              | 45.0 | 27.5 | —    | Bismuth solder.                    |
| 94.4        | 33.9                              | 11.6 | 54.5 | —    | Newton                             |
| 95.         | 43.3                              | —    | 50.1 | 6.7  | Hauer.                             |
| 104.0       | 26.3                              | 7.5  | 66.2 | —    | Krafft.                            |
| 111.0       | 40.0                              | 20.0 | 40.0 | —    | Bismuth solder.                    |
| 122.        | 29.3                              | 21.2 | 39.5 | —    | Homborg.                           |
| 155.        | 42.9                              | 42.9 | 14.3 | —    | Bismuth solder.                    |
| 182.        | 37.1                              | 62.9 | —    | —    | Soft solder.                       |
|             | Cu.                               | Zn.  |      |      |                                    |
| 870—845     | 50.                               | 50.  | —    | —    | Common brass or<br>brazing spelter |

## Melting Points of Alloys of Precious Metals.

| Percentage Composition. |                      | Temperature at which melting begins. | Temperature at which melting is complete. |
|-------------------------|----------------------|--------------------------------------|---|
| Au. Pt.                 |                      |                                      |   |
| (Doerinckel 1907)       |                      |                                      |   |
| 100                     | 0                    | —                                    | 1064                                      |
| 90                      | 10                   | 1079                                 | 1174                                      |
| 80                      | 20                   | 1109                                 | 1299                                      |
| 70                      | 30                   | 1177                                 | 1437                                      |
| 60                      | 40                   | 1203                                 | 1503                                      |
| 50                      | 50                   | 1253                                 | 1544                                      |
| 40                      | 60                   | 1285                                 | 1579                                      |
| [ 0                     | 100 by extrapolation |                                      | 1744]                                     |
| Au. Ag.                 |                      |                                      |   |
| (Raydt 1912)            |                      |                                      |   |
| 100                     | 0                    | —                                    | 1064                                      |
| 80                      | 20                   | 1038                                 | 1046                                      |
| 60                      | 40                   | 1018                                 | 1028                                      |
| 40                      | 60                   | 993                                  | 1003                                      |
| 20                      | 80                   | 976                                  | 985                                       |
| 0                       | 100                  | —                                    | 961                                       |

## Specific Heat of Water. Callendar, 1912.

| 15° calories. |        |    |       |    |        |     |        |
|---------------|--------|----|-------|----|--------|-----|--------|
| 0°            | 1·0093 | 30 | ·9976 | 60 | ·9987  | 90  | 1·0036 |
| 5             | 1·0049 | 35 | ·9973 | 65 | ·9993  | 95  | 1·0046 |
| 10            | 1·0019 | 40 | ·9973 | 70 | 1·0000 | 100 | 1·0057 |
| 15            | 1·0000 | 45 | ·9975 | 75 | 1·0008 |     |        |
| 20            | 0·9988 | 50 | ·9978 | 80 | 1·0017 |     |        |
| 25            | 0·9980 | 55 | ·9982 | 85 | 1·0026 |     |        |

# Specific Heats and Latent Heats of Vaporisation of Common Liquids. Cals. per gm.

Latent heats of vaporisation of liquids not mentioned may be found approximately by Trouton's rule.  $ML=CT$  where  $M$  is mol. wt.,  $T$  is boiling point absolute and  $C=21$  for normal liquids: if liquid is associated  $C>21$ , if vapour is associated  $C<21$ .

|   | °C.       | Specific heat. | B.Pt. °C. | Lt. heat of vaporisation. |
|---|-----------|----------------|-----------|---------------------------|
| Ammonia liquid .....                                    | 0         | 1·10*          | (0)       | (301·8)                   |
| Brine (s.g. 1·20) .....                                 | 0         | ·71            | —         | —                         |
| CaCl <sub>2</sub> solution (s.g. 1·20) .....            | 0         | ·708           | —         | —                         |
| Carbon dioxide liquid .....                             | 0         | ·60*           | (0)       | (54·1)                    |
| disulphide .....  | 0         | ·235           | 46·2      | 84·9                      |
| Sulphur monochloride S <sub>2</sub> Cl <sub>2</sub> ..  | 12—70     | ·220           | 57·       | 36·                       |
| Sulphur dioxide .....                                   | 20        | ·327           | (0)       | (91·7)                    |
| Sulphuric acid .....                                    | 10        | ·34            | —         | —                         |
| Sulphuryl chloride SO <sub>2</sub> Cl <sub>2</sub> .... | 15—63     | ·233           | 70·       | 52·4                      |
| Thionyl chloride SOCl <sub>2</sub> .....                | 17—60     | ·242           | 80·       | 54·4                      |
| Water .....   | see table |                | 100·      | 539·0†                    |
| Acetone .....   | 0         | ·506           | 56·0      | 124·                      |
| Amyl acetate (iso) .....                                | 20        | ·459           | 139·      | 69·                       |
| alcohol (iso) .....                                     | 20        | ·555           | 130·1     | 116·                      |
| Aniline .....   | 15        | ·514           | 183·      | 104·                      |
| Benzene .....   | 0         | ·383           | 80·2      | 94·9                      |
| Benzyl alcohol .....                                    | 22—200    | ·540           | 205·3     | 98·5                      |
| Butyl acetate .....                                     | 20        | ·459           | 124·2     | 73·9                      |
| Carbon tetrachloride .....                              | 30        | ·203           | 77·8      | 46·8                      |
| Chloroform .....  | 0         | ·232           | 61·       | 61·                       |
| Ether .....   | 0         | ·523           | (30)      | (91·3)                    |
| Ethyl acetate .....                                     | 20        | ·459           | 77·3      | 88·4                      |
| alcohol .....   | 20        | ·574           | 78·2      | 204·                      |
| Glycerine .....   | 20        | ·551           | —         | —                         |
| Methyl alcohol .....                                    | 0         | ·563           | 66·2      | 262·                      |
| Nitrobenzene .....                                      | 20        | ·386           | 210·      | 79·1                      |
| Pyridine .....  | 21—108    | ·431           | 114·      | 104·                      |
| Toluene .....   | 18        | ·402           | 110·8     | 87·4                      |
| Xylene <i>m</i> .....                                   | 0         | ·383           | 139·2     | 81·3                      |

\* At constant (saturation) pressure.

† Accurate value, 15° cals



## Specific Heats and Thermal Conductivities of Miscellaneous Substances.

$c$  = specific heat cals. per gm.

$k$  = thermal conductivity

The values are approximate and except where otherwise stated are for room temperatures.

|   | $c$ . | $k \times 10^4$ |
|---|-------|-----------------|
| Asbestos .....                                  | ·20   | —               |
| Cellulose 7% $H_2O$ .....                       | ·41   | ·4 (cotton)     |
| Charcoal .....                                  | ·16   | 2·2             |
| Ebonite .....                                   | ·40   | 4·2             |
| Glass, crown .....                              | ·17   | 25·             |
| flint .....                                     | ·12   | 20·             |
| Jena 16''' & 59''' .....                        | 20    | 15·             |
| Ice ( $-10^\circ C.$ ) .....                    | ·53   | 40·             |
| Paraffin wax .....                              | ·73   | 6·0             |
| oil .....                                       | ·51   | 3·5             |
| Porcelain ( $15^\circ$ — $950^\circ C.$ ) ..... | ·26   | 25·             |
| Quartz .....                                    | ·18   | 160·            |
| Silica (fused) $0^\circ$ .....                  | ·168  | —               |
| 1000° .....                                     | ·286  | —               |
| Wood (average) .....                            | ·42   | 5·              |

## Latent Heats of Fusion of Compounds at Melting Point. Cals. per gm.

|                         | $^\circ C.$ | Lat. heat. |
|-------------------------|-------------|------------|
| Potassium nitrate ..... | 333·        | 25·5       |
| Sodium nitrate .....    | 308·        | 45·        |
| Sulphuric acid .....    | 10·5        | 26·0       |
| Water .....             | 0·          | 79·6*      |
| Acetic acid .....       | 16·54       | 45·8*      |
| Benzene .....           | 5·44        | 30·4*      |
| Chloral hydrate .....   | 46·         | 33·        |
| Formic acid .....       | 8·          | 53·        |
| Naphthalene .....       | 79·9        | 36·        |
| Nitrobenzene .....      | 5·82        | 22·46*     |
| Phenol .....            | 43·         | 24·9       |

\*Very accurate determinations— $15^\circ$  calories.

## Physical Properties of Gases.

$c_p$  = specific heat at constant pressure (1 atmo.) cals. per gm.

$\gamma$  = ratio of  $c_p$  to specific heat at constant volume.

$\eta_o$  = viscosity at 0°C. in C.G.S. units.

C = constant in Sutherland's formula  $\eta_t = \eta_o \frac{273 + C}{\theta + C} \cdot \left( \frac{\theta}{273} \right)^{3/2}$

in which  $\theta$  is absolute temp.

$k_o$  = thermal conductivity at 0°C., cals. per sq. cm. per second for temperature gradient of 1°C. per cm

$\beta$  = temperature coefficient of  $k$ .

| Gas.               | T°     | $c_p$ | T°  | $\gamma$ | $\eta_o \times 10^6$ | C.  | $k_o \times 10^5$ | $\beta \times 10^3$ |
|--------------------|--------|-------|-----|----------|----------------------|-----|-------------------|---------------------|
| Air .....          | 20°    | ·2408 | 19  | 1·4029   | 171·8                | 120 | 5·68*             | 3·6                 |
|                    | 20—800 | ·243  |     |          |                      |     |                   |                     |
| Ammonia .....      | 0      | ·308  | —   | 1·336    | —                    | —   | 4·58              | 5·5                 |
| Argon .....        | 20—90  | ·123  | 0   | 1·667    | 210                  | 170 | 3·85*             | 3·5                 |
| Carbon monoxide    | 23—99  | ·242  | 0   | 1·401    | 163                  | 102 | 5·0               | —                   |
| dioxide ..         | 20     | ·202  | 25  | 1·300    | 139                  | 240 | 3·53*             | 5·6                 |
| Chlorine .....     | 16—343 | ·115  | 16  | 1·329    | 129                  | —   | —                 | —                   |
| Ethylene .....     | 25—100 | ·388  | —   | 1·264    | 97                   | 226 | 3·95              | —                   |
| Helium .....       | 0—150  | 1·266 | 0   | 1·63     | 189                  | 80  | 34·4*             | 2·8                 |
| Hydrogen .....     | 20—100 | 3·41  | 19  | 1·4012   | 84                   | 83  | 41·65*            | 2·8                 |
| Methane .....      | —      | ·59   | 19  | 1·313    | 104                  | —   | 7·20*             | 4·8                 |
| Nitric oxide ..... | 10—180 | ·232  | —   | 1·394    | 165                  | —   | 4·5               | —                   |
| Nitrogen .....     | 0      | ·2350 | —   | 1·4144   | 167                  | 111 | 5·66*             | 3·4                 |
| peroxide           | 27—67  | 1·62  | 20  | 1·172    | —                    | —   | —                 | —                   |
| Nitrous oxide....  | 25—100 | ·212  | —   | 1·261    | 135                  | 313 | 3·53*             | 4·4                 |
| Oxygen .....       | 20—440 | ·224  | 10  | 1·398    | 193                  | 138 | 5·77*             | 3·6                 |
| Sulphur dioxide..  | 10—190 | ·154  | 25  | 1·26     | 123                  | —   | —                 | —                   |
| Sulphuretted       |        |       |     |          |                      |     |                   |                     |
| hydrogen           | 20—206 | ·245  | 18  | 1·321    | 115                  | —   | —                 | —                   |
| Water vapour ..    | 100    | ·435  | 110 | 1·305    | 88                   | 72  | 3·95              | —                   |

\* Signifies due to Weber, 1917.

NOTE.—In mixtures, specific heats are additive, but neither viscosity nor thermal conductivity is proportional to the concentration.

## Viscosity

The C.G.S. unit of viscosity is that of a fluid in which the tangential force per sq. cm. exerted on each of two parallel planes 1 cm. apart in the fluid is one dyne when one of the planes is moving with a velocity of 1 cm. per sec. in its own plane relatively to the other.

In the capillary-tube method of determining viscosities

$$\eta = \frac{\pi p r^4 t}{8v(l + \lambda)} - \frac{mcv}{8\pi t(l + \lambda)}$$

where  $p$  = pressure difference between the two ends of the tube (dynes/cm.<sup>2</sup>).

$t$  = time of flow.

$c$  = density of the fluid.

$r$  = radius of capillary,  $l$  = length.

$v$  = volume flowing in time  $t$ .

and  $m$  = a constant, = about 1.12.

$\lambda$  = a correction for resistances outside the capillary, negligible if capillary is long compared with its radius.

From the approximate dimensions of the apparatus used find  $B = \frac{mcv}{8\pi l}$ , then  $\eta = A\dot{p}t - B \frac{c}{t}$ , and the value of  $A$  may be obtained by calibration with a substance of known viscosity,  $\eta_1$  by substituting the corresponding values of  $p$ ,  $t$ , and  $c$ , found for the standard, when  $A = (\eta_1 + B c_1/t_1) \div p_1 t_1$

In all relative measurements of viscosity the most accurate results are obtained by using as standard substance one which has a viscosity not far removed from that being measured. In commercial viscometry, where short-tube instruments or approximate methods are likely to be used, it is best to refer the results, not in most cases to the time of flow of water, but to the viscosity or time of flow of a solution of alcohol or of cane sugar (sucrose) in water having a viscosity as near as possible to the range desired.

Bingham and Jackson (*Bull. Bureau of Standards*, 1918)

give the following values for the viscosity of standard substances in C.G.S. units.

## WATER.

| $t^{\circ}\text{C.}$ | $\eta \times 100.$ | $t^{\circ}\text{C.}$ | $\eta \times 100.$ | $t^{\circ}\text{C.}$ | $\eta \times 100.$ |
|----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| 0                    | 1.7921             | 25                   | 0.8937             | 60                   | 0.469              |
| 5                    | 1.5188             | 30                   | 0.8007             | 70                   | 0.406              |
| 10                   | 1.3077             | 35                   | 0.7225             | 80                   | 0.356              |
| 15                   | 1.1404             | 40                   | 0.656              | 90                   | 0.316              |
| 20                   | 1.0050             | 50                   | 0.549              | 100                  | 0.284              |

For other temperatures interpolate reciprocals of  $\eta$ , or, more accurately, use equation

$$1/\eta = 2.1482 \left\{ (t - 8.435) + \sqrt{8078.4 + (t - 8.435)} \right\} - 122.$$

ETHYL ALCOHOL-WATER MIXTURE containing 39% by weight of alcohol (solution of maximum viscosity).

| $t^{\circ}\text{C.}$ | 0    | 5    | 10   | 15   | 20   | 25   | 30   | 40    | 50    |
|----------------------|------|------|------|------|------|------|------|-------|-------|
| $\eta \times 100$    | 7.25 | 5.62 | 4.39 | 3.52 | 2.88 | 2.35 | 2.00 | 1.473 | 1.124 |

SUCROSE SOLUTIONS  $\eta \times 100.$ 

| $t^{\circ}\text{C.}$ | gms. sucrose in 100 gms. soln. |       |       | $t^{\circ}\text{C.}$ | gms. sucrose in 100 gms. soln. |       |       |
|----------------------|--------------------------------|-------|-------|----------------------|--------------------------------|-------|-------|
|                      | 20                             | 40    | 60    |                      | 20                             | 40    | 60    |
| 0                    | 3.804                          | 14.77 | 238.  | 30                   | 1.504                          | 4.382 | 33.78 |
| 5                    | 3.154                          | 11.56 | 156.  | 35                   | 1.331                          | 3.762 | 26.52 |
| 10                   | 2.652                          | 9.794 | 109.8 | 40                   | 1.193                          | 3.249 | 21.28 |
| 15                   | 2.267                          | 7.468 | 74.6  | 50                   | 0.970                          | 2.497 | 14.01 |
| 20                   | 1.950                          | 6.200 | 56.5  | 60                   | 0.808                          | 1.982 | 9.83  |
| 25                   | 1.704                          | 5.187 | 43.86 |                      |                                |       |       |

For other concentrations interpolate logs. of  $\frac{1}{n} \log. \frac{\eta}{\eta_0}$  where  $n$  is normality of solution (gm. mols. sucrose per litre) and  $\eta_0$  is viscosity of water at the temperature considered.

# Viscosities of Various Liquids in C.G.S. units $\times 100$ (Mostly after Thorpe and Roger).

|                            | 0°C. | 20°C. | 40°C.         | 60°C. |
|----------------------------|------|-------|---------------|-------|
| Acetone .....              | —    | ·33   | —             | —     |
| Acetic acid .....          | —    | 1·22  | ·90           | ·70   |
| Aniline .....              | —    | ·44   | ·24           | ·16   |
| Benzene .....              | ·90  | ·65   | ·49           | ·39   |
| Bromine .....              | 1·26 | ·99   | ·82           | —     |
| Carbon tetrachloride ..... | 1·35 | ·97   | ·74           | ·58   |
| “ disulphide.....          | ·43  | ·37   | ·32           | —     |
| „ dioxide liq. ....        | —    | ·07   | —             | —     |
| Chloroform .....           | ·70  | ·56   | ·46           | ·39   |
| Ether .....                | ·29  | ·23   | —             | —     |
| Ethyl alcohol .....        | 1·77 | 1·19  | ·83           | ·59   |
| Hexane ( <i>n</i> ) .....  | ·40  | ·32   | ·26           | ·22   |
| Mercury .....              | 1·69 | 1·56  | — (100° 1·22) | —     |
| Methyl alcohol .....       | ·81  | ·59   | ·45           | ·35   |
| Toluene .....              | ·77  | ·59   | ·47           | ·38   |
| Xylene ( <i>m</i> ) .....  | ·80  | ·61   | ·49           | ·40   |

## Viscosities of Miscellaneous Substances of High Viscosity in C.G.S. units.

| Oils (Archbutt) .....   | 15°C.            | 100°C.    |
|-------------------------|------------------|-----------|
| sperm .....             | ·42              | ·046      |
| olive .....             | 1·01             | ·070      |
| rape .....              | 1·12—1·18        | ·080—·085 |
| castor .....            | 2·73 (38°C.)     | ·169      |
| spindle (mineral) ..... | ·45—·73          | ·033—·039 |
| machine (medium) .....  | 3·0—3·6          | ·08—·07   |
| cylinder .....          | 2·0—11·0 (38°C.) | ·2—·45    |

|  | $\eta$ | $t^\circ\text{C.}$ |
|--|--------|--------------------|
| Glycerine (s.g. 1·262) .....               | 13·1   | at 20              |
| Sulphuric acid 96%.....                    | 0·22   | at 20              |
| Sodium nitrate, fused .....                | 0·030  | 305                |
| „ „ „ .....                                | 0·020  | 355                |
| Potassium nitrate, fused .....             | 0·021  | 334                |
| „ „ „ .....                                | 0·017  | 358                |
| Sodium chloride 20% solution in water..... | 0·0154 | 20°                |

|                             |      |                          |      |                          |
|-----------------------------|------|--------------------------|------|--------------------------|
| Pitch (Trouton) .....       | 0°   | $5\cdot1 \times 10^{11}$ | 15°  | $1\cdot3 \times 10^{10}$ |
| Soda glass (Trouton) .....  | 575° | $1\cdot1 \times 10^{13}$ | 710° | $4\cdot5 \times 10^{10}$ |
| Cobblers' wax (Trouton) ... | 8°   | $4\cdot7 \times 10^6$    |      |                          |

## Refractive Indices.

Of *Liquids* for sodium D line at 15° C. (against air).

|                              | $n-1$ . |                           | $n-1$ . |
|------------------------------|---------|---------------------------|---------|
| Acetic acid .....            | ·374    | Ethyl alcohol .....       | ·363    |
| anhydride .....              | ·392    | ether .....               | ·355    |
| Acetone .....                | ·361    | Ethylene dibromide .....  | ·541    |
| Amyl acetate .....           | ·406    | Glycerine .....           | ·475    |
| alcohol ( <i>iso</i> ) ..... | ·409    | Methylene iodide .....    | ·744    |
| Aniline .....                | ·589    | Methyl alcohol .....      | ·331    |
| Benzene .....                | ·504    | Naphthalene bromide ..... | ·660    |
| Benzyl alcohol .....         | ·541    | Nitrobenzene .....        | ·554    |
| Bromoform .....              | ·591    | Phenol .....              | ·552    |
| Canada balsam .....          | ·53     | Pyridine .....            | ·509    |
| Carbon disulphide .....      | ·631    | Sulphuric acid .....      | ·420    |
| tetrachloride .....          | ·463    | Toluene .....             | ·498    |
| Chloroform .....             | ·449    | Water .....               | ·333    |
| Ethyl acetate .....          | ·374    | Xylene <i>m</i> .....     | ·499    |

Of *Solids* for sodium D line.

|                          | $n$ .     | $\delta n \times 10^3$ . |
|--------------------------|-----------|--------------------------|
| Diamond .....            | 2·417     | 24                       |
| Glass                    |           |                          |
| crown .....              | 1·50—1·52 | 8·5—10·0                 |
| borosilicate crown ..... | 1·48—1·52 | 7·6—8·6                  |
| barium crown .....       | 1·57—1·65 | 10·0—13·0                |
| flint .....              | 1·54—1·80 | 12· —30·                 |
| borosilicate flint ..... | 1·55—1·57 | 11· —12·                 |
| barium flint .....       | 1·55—1·63 | 10· —17·                 |

$\delta n$  is difference between refractive indices for C line and F line ( $H\alpha$  and  $H\beta$ ).

Of *Gases* for sodium D line, reduced to N.T.P.

|                       | $(n-1) \times 10^6$ . |                          | $(n-1) \times 10^6$ . |
|-----------------------|-----------------------|--------------------------|-----------------------|
| Air .....             | 291·8                 | Hydrogen .....           | 138·4                 |
| Acetylene .....       | 565·1                 | Methane .....            | 443·8                 |
| Ammonia .....         | 377·                  | Nitrogen .....           | 298·                  |
| Argon .....           | 283·7                 | Nitrous oxide .....      | 515·                  |
| Carbon monoxide ..... | 334·                  | Nitric oxide .....       | 297·                  |
| dioxide .....         | 450·                  | Oxygen .....             | 272·                  |
| Chlorine .....        | 769·                  | Sulphur dioxide .....    | 660·                  |
| Chloroform .....      | 1456·                 | Sulphuretted hydrogen .. | 619·                  |
| Ethylene .....        | 657·1                 | Water vapour .....       | 257·                  |
| Helium .....          | 35·0                  |                          |                       |

For  $n$  of oils see Oils, Fats and Waxes Section.



## Cryoscopic Constants.

For small concentrations of dissolved substance, Raoult's law states that  $\frac{\delta\theta}{m} = \frac{k_c}{M}$  where  $\delta\theta$  is lowering of freezing point produced by the addition of  $m$  gms. of solute of molecular weight  $M$  to 100 gms. of solvent:  $k_c$  is called the cryoscopic constant of the solvent. The theoretical value of  $k_c$  is  $0.02\theta^2$   $\frac{L}{\theta}$  where  $\theta$  is the absolute freezing point and  $L$  the latent heat of fusion of the solvent.

|                      | $k_c$ |   | $k_c$ |
|----------------------|-------|---|-------|
| Acetamide .....      | 36.3  | Naphthalene .....                         | 68.7  |
| Acetic acid .....    | 39.0  | Nitrobenzene .....                        | 69.5  |
| Aniline .....        | 63.6  | Phenol .....                              | 73.   |
| Benzene .....        | 50.   | Stearic acid .....                        | 43.5  |
| Bromoform .....      | 144.  | Water .....                               | 18.5  |
| Formamide .....      | 38.5  | Sulphuric acid .....                      | 69.   |
| Iodine .....         | 213.  | Sodium sulphate $10\text{H}_2\text{O}$ .. | 32.5  |
| Methyl oxalate ..... | 52.   |   |       |

## Ebullioscopic Constants.

The elevation of boiling-point of a solvent by the addition to 100 gms. of it of  $m$  gms. of solvent of molecular weight  $M$  is given by the relation  $\frac{\delta\theta}{m} = \frac{k_e}{M}$ , provided  $m$  is small:  $k_e$  is the ebullioscopic constant. The theoretical value of  $k_e$  may be calculated from the relation  $k_e = \frac{0.02\theta^2}{L}$  where  $\theta$  is the absolute boiling-point at 760 mm. and  $L$  the latent heat of vaporisation at  $\theta$  of the solvent. The constants given are for atmospheric pressure: Raoult gives the formula

$$k_e^1 = k_e \left\{ 1 + 0.08(\theta^1 - \theta) \right\}$$

for the variation of the constant with pressure:  $k_e^1$  is the

constant when the pressure change has altered the boiling point from  $\theta$  to  $\theta^1$ .

|                              | $k_e$ |                      | $k_e$ |
|------------------------------|-------|----------------------|-------|
| Acetic acid .....            | 30.7  | Ether .....          | 21.3  |
| anhydride .....              | 35.3  | Ethyl acetate .....  | 28.   |
| Acetone .....                | 16.7  | alcohol .....        | 11.9  |
| Amyl acetate .....           | 48.3  | Methyl alcohol ..... | 8.8   |
| alcohol ( <i>iso</i> ) ..... | 25.7  | Naphthalene .....    | 58.   |
| Aniline .....                | 36.9  | Nitrobenzene .....   | 53.   |
| Benzene .....                | 25.6  | Phenol .....         | 36.0  |
| Carbon disulphide .....      | 23.7  | Pyridine .....       | 29.   |
| tetrachloride .....          | 48.5  | Water .....          | 5.2   |
| Chloroform .....             | 38.8  |                      |       |

### DENSITY AND SPECIFIC GRAVITY.

*The Density* of a substance is defined as its mass per unit volume.

Since the volume of a given mass of any substance varies with the temperature of the substance, its density also varies with the temperature. Hence, when stating the density of a substance, it is necessary also to state the temperature to which the density refers.

Densities are usually expressed in gms. per millilitre or in gms. per cc.

From the definition of the litre \* it follows that the density of water at 4°C. expressed in gms. per ml. is unity.

*The Specific Gravity* of a substance is the ratio of the mass of any given volume of the substance to the mass of an equal volume of water.

The temperature of the substance and also that of the water must be specified. A very commonly accepted method of expressing briefly the exact significance of the specific

gravity of a substance is to use the abbreviation  $S_{t_s}^{t_w}$

where  $t_s$  is the temperature of the substance and  $t_w$  the temperature of the water to which it is referred.

\* The litre is defined as the volume occupied by 1 kilogramme of water under a pressure of 760 mm. at its temperature of maximum density (4°C). The weighing is corrected for the buoyancy of the air. According to the latest determination 1 litre=1000.027 cc. and hence the millilitre, or thousandth part of a litre, and the cubic centimetre are not identical. For many purposes the difference between the two units is negligible, amounting as it does to only 27 parts in a million, but for accurate work it must be taken into account.

Thus for example  $\frac{S^{15^{\circ}\text{C.}}}{4^{\circ}\text{C.}}$  signifies that the specific gravity in question is the ratio of the mass of any given volume of the substance at  $15^{\circ}\text{C.}$  to the mass of that quantity of water which at  $4^{\circ}\text{C.}$  occupies a volume equal to that of the substance at  $15^{\circ}\text{C.}$

The specific gravity of a substance at any temperature  $t_s$ , relative to water at any temperature  $t_w$  may be converted into the density of the substance at  $t_s$  by multiplying the specific gravity  $\frac{S^{t_s}}{t_w}$  by the density of water at the temperature  $t_w$ .

Since the density of water at  $4^{\circ}\text{C.}$ , expressed in gms. per millilitre, is unity (see above), it follows that specific gravities expressed by  $\frac{S^{t_s}}{4^{\circ}\text{C.}}$  are identical with densities in gms. per millilitre at the temperature  $t_s$ .

## DETERMINATION OF DENSITIES AND SPECIFIC GRAVITIES.

### (A) LIQUIDS.

Since all liquids have high coefficients of cubical expansion, their densities change rapidly with change of temperature. Hence it is of fundamental importance to secure accurate temperature control in all determinations of the density, or the specific gravity, of a liquid.

#### (1) *By means of a hydrometer.*

When a fairly large quantity, say 500 cc., of the liquid is available, its density, or specific gravity, may be readily determined by means of a hydrometer. Results accurate to three places of decimals can be easily and rapidly obtained with a suitably scaled instrument. To obtain this precision the graduated portion of the hydrometer should be about six inches in length and cover a range of five units in the second place of decimals. For less accurate results a more closely scaled instrument may be used. The temperature of the liquid must be carefully adjusted to the standard temperature of the hydrometer, or, if readings are taken at other temperatures, suitable corrections must be applied.

Hydrometers graduated in terms of specific gravity, or density, are preferable to those graduated in arbitrary scales.

#### (2) *By means of a specific gravity bottle or pyknometer*

The weight of water required to fill the bottle or pyknometer must be determined, and also the weight of liquid required to fill the instrument, and from these observations the density,

or the specific gravity of the liquid may be calculated as follows :—

If  $W_1$  = observed weight in air of water required to fill the bottle at  $t^\circ\text{C}$ .

$W_2$  = observed weight in air of liquid required to fill the bottle at  $t^\circ\text{C}$ .

$D$  = density of liquid in gms. per ml. at  $t^\circ\text{C}$ .

$d$  = density of water in gms. per ml. at  $t^\circ\text{C}$ .

$S$  = the specific gravity of the liquid at  $t^\circ\text{C}$ . relative to water at  $t^\circ\text{C}$ .

$$\text{Then } D = \frac{W_2}{W_1} d \quad \text{and} \quad S = \frac{W_2}{W_1}$$

The approximate values given by the above formulæ may be corrected for the buoyancy effect of the air by means of the following relations :—

$$D' = D - 0.0012 (D - 1),$$

$$\text{and } S' = S - 0.0012 (S - 1),$$

where  $D'$  and  $S'$  are the corrected values.

If the weight of water  $W_1$  is determined at  $t'$ , and the weight of liquid  $W_2$  is determined at  $t$ , then the following relations give values corrected for the temperature difference and also for the buoyancy effect of the air :—

$$D'' = D - 0.0012 (D - 1) + 0.000026 (t' - t) D,$$

$$\text{and } S'' = S - 0.0012 (S - 1) + 0.000026 (t' - t) S$$

$$\text{where } D = \frac{W_2}{W_1} d \quad \text{and} \quad S = \frac{W_2}{W_1}$$

(3) *By means of a plummet or sinker.*

The weight of the plummet in air, its weight when suspended in water, and also its weight when suspended in the liquid must be determined. Then if  $W_1$  is the difference between the weight in air and the weight in water, and  $W_2$  is similarly the difference between the weight in air and the weight in the liquid, the water and the liquid both being at the same temperature  $t$ , the required density or specific gravity may be determined by substituting these values in the relations given in the preceding paragraph, viz. :

$$D = \frac{W_2}{W_1} d \quad \text{and} \quad S = \frac{W_2}{W_1}$$

and to correct for the buoyancy effect of the air :

$$D' = D - 0.0012 (D - 1) \quad \text{and} \quad S' = S - 0.0012 (S - 1)$$

Also if the temperature of the water is  $t'$  and that of the liquid  $t$ , we have as before :

$$D'' = D - 0.0012 (D - 1) + 0.000026 (t' - t) D,$$

$$\text{and } S'' = S - 0.0012 (S - 1) + 0.000026 (t' - t) S.$$

## (B) SOLIDS.

(1) *By weighing in air and also in water.*

Let  $W_1$  = weight of the solid in air.

$W_2$  = weight of the solid in water at temp.  $t$ .

$d$  = density of water in gms. per ml. at  $t$ .

$D$  = density of solid in gms. per ml. at  $t$ .

$S$  = specific gravity of solid at  $t$  relative to water at  $t$ .

$$\text{Then } D = \frac{W_1}{W_1 - W_2} d, \text{ and } S = \frac{W_1}{W_1 - W_2}$$

The above approximate values may be corrected for the buoyancy effect of the air by means of the relations :

$$D' = D - 0.0012 (D - 1)$$

$$S' = S - 0.0012 (S - 1)$$

where  $D'$  and  $S'$  are the corrected values.

(2) *By means of a specific gravity bottle.*

The density, or the specific gravity, of a solid may be conveniently determined by means of a specific gravity bottle when the substance is in small fragments or in the form of a powder.

Let  $W_1$  = weight of solid.

$W_2$  = weight of water at a temp.  $t^\circ\text{C}$ . required to fill the bottle when it contains the weight  $W_1$  of solid.

$W_3$  = weight of water at a temp.  $t^\circ\text{C}$ . required to fill the bottle completely.

$D$  = density of solid in gms. per ml. at  $t^\circ\text{C}$ .

$d$  = density of water in gms. per ml. at  $t^\circ\text{C}$ .

$S$  = specific gravity of solid at  $t$  relative to water at  $t$ .

$$\text{Then } D = \frac{W_1}{W_3 - W_2} d, \dots\dots\dots(1)$$

$$\text{and } S = \frac{W_1}{W_3 - W_2} \dots\dots\dots(2)$$

If  $W_2$  is determined when the water is at a temp.  $t^\circ\text{C}$ ., and  $W_3$  is determined when the water is at a temp.  $t'^\circ\text{C}$ ., and if  $d$  and  $d'$  are the densities of water at  $t$  and  $t'$  respectively, the quantity

$$W_3 [1 + d - d' + 0.000026 (t - t')] ]$$

must be used instead of  $W_3$  in the above formulæ in order to correct for the difference in temp.

The values  $D$  and  $S$  obtained by using the relations (1) and (2) respectively (or by introducing the corrected value of  $W_3$  in these relations) may be corrected for the buoyancy effect of the air by the usual equation :

$$D' = D - 0.0012 (D - 1)$$

$$\text{and } S' = S - 0.0012 (S - 1)$$

where  $D'$  and  $S'$  are the corrected values.

# BOUYANCY CORRECTIONS FOR SPECIFIC GRAVITY DETERMINATIONS.

| Sp. Gr. | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
|---------|------|------|------|------|------|------|------|------|------|------|
| 0.6     | -5   | -5   | -5   | -4   | -4   | -4   | -4   | -4   | -4   | -4   |
| 0.7     | -4   | -3   | -3   | -3   | -3   | -3   | -3   | -3   | -3   | -3   |
| 0.8     | -2   | -2   | -2   | -2   | -2   | -2   | -2   | -2   | -1   | -1   |
| 0.9     | -1   | -1   | -1   | -1   | -1   | -1   | 0    | 0    | 0    | 0    |
| 1.0     | 0    | 0    | 0    | 0    | 0    | +1   | +1   | +1   | +1   | +1   |
| 1.1     | +1   | +1   | +1   | +2   | +2   | +2   | +2   | +2   | +2   | +2   |
| 1.2     | +2   | +3   | +3   | +3   | +3   | +3   | +3   | +3   | +3   | +3   |
| 1.3     | +4   | +4   | +4   | +4   | +4   | +4   | +4   | +4   | +5   | +5   |
| 1.4     | +5   | +5   | +5   | +5   | +5   | +5   | +6   | +6   | +6   | +6   |
| 1.5     | +6   | +6   | +6   | +6   | +6   | +7   | +7   | +7   | +7   | +7   |
| 1.6     | +7   | +7   | +7   | +8   | +8   | +8   | +8   | +8   | +8   | +8   |
| 1.7     | +8   | +9   | +9   | +9   | +9   | +9   | +9   | +9   | +9   | +9   |
| 1.8     | +10  | +10  | +10  | +10  | +10  | +10  | +10  | +10  | +11  | +11  |
| 1.9     | +11  | +11  | +11  | +11  | +11  | +11  | +12  | +12  | +12  | +12  |
| 2.0     | +12  | +12  | +12  | +12  | +12  | +13  | +13  | +13  | +13  | +13  |

## NOTE.

The table gives the values of  $0.0012 (S - 1)$  where  $S$  is the uncorrected specific gravity, the results being expressed as units in the *fourth decimal* place. The table may also be used for correcting densities, for in this case also the correction term is  $0.0012 (D - 1)$ . The corrections given are to be subtracted in either case.

If the final result is required to be correct to five or more places of decimals the atmospheric conditions prevailing at the time of experiment must be noted and appropriate values for the density of the air used in calculating the buoyancy corrections (see "Density of Air half saturated with Water Vapour").

*Example.* Suppose a specific gravity to have been calculated using a simple formula without any allowance for the buoyancy effect of the air, and found to be 0.7436. Then in the above table, under 0.74, we find the correction - 3. Hence the corrected value of the specific gravity is  $0.7436 + 0.0003$ , i.e. 0.7439.

By means of this and the following table, specific gravities calculated by using one or other of the various simple formulæ\* may be corrected for the buoyancy effect of the air and converted into true densities by simple addition or subtraction.

\* For example  $S = \frac{W_2}{W_1}$ , where  $W_2$  is the observed weight of a liquid required to fill a specific gravity bottle and  $W_1$  is the observed weight of water required to fill the bottle at the same temperature.

## CONVERSION OF SPECIFIC GRAVITIES TO DENSITIES.

| Sp.<br>Gr. | S <sub>10°C.</sub><br>10°C. | S <sub>12.5°C.</sub><br>12.5°C. | S <sub>15°C.</sub><br>15°C. | S <sub>60°F.</sub><br>60°F. | S <sub>17°C.</sub><br>17°C. | S <sub>17.5°C.</sub><br>17.5°C. | S <sub>20°C.</sub><br>20°C. |
|------------|-----------------------------|---------------------------------|-----------------------------|-----------------------------|-----------------------------|---------------------------------|-----------------------------|
| 0.60       | 16                          | 32                              | 52                          | 58                          | 72                          | 77                              | 106                         |
| 0.65       | 18                          | 35                              | 57                          | 62                          | 78                          | 83                              | 115                         |
| 0.70       | 19                          | 37                              | 61                          | 67                          | 84                          | 90                              | 124                         |
| 0.75       | 20                          | 40                              | 66                          | 72                          | 90                          | 96                              | 132                         |
| 0.80       | 22                          | 43                              | 70                          | 77                          | 96                          | 103                             | 141                         |
| 0.85       | 23                          | 45                              | 74                          | 81                          | 102                         | 109                             | 150                         |
| 0.90       | 24                          | 48                              | 79                          | 86                          | 108                         | 116                             | 159                         |
| 0.95       | 26                          | 51                              | 83                          | 91                          | 114                         | 122                             | 168                         |
| 1.00       | 27                          | 53                              | 87                          | 96                          | 120                         | 129                             | 177                         |
| 1.05       | 29                          | 56                              | 92                          | 100                         | 126                         | 135                             | 185                         |
| 1.10       | 30                          | 59                              | 96                          | 106                         | 131                         | 141                             | 194                         |
| 1.15       | 31                          | 61                              | 100                         | 110                         | 137                         | 148                             | 203                         |
| 1.20       | 33                          | 64                              | 105                         | 115                         | 143                         | 154                             | 212                         |
| 1.25       | 34                          | 67                              | 109                         | 120                         | 149                         | 161                             | 221                         |
| 1.30       | 35                          | 69                              | 114                         | 125                         | 155                         | 167                             | 230                         |
| 1.35       | 37                          | 72                              | 118                         | 130                         | 161                         | 173                             | 238                         |
| 1.40       | 38                          | 75                              | 122                         | 134                         | 167                         | 180                             | 247                         |
| 1.45       | 39                          | 77                              | 127                         | 139                         | 173                         | 186                             | 256                         |
| 1.50       | 41                          | 80                              | 131                         | 144                         | 179                         | 193                             | 265                         |
| 1.55       | 42                          | 83                              | 135                         | 149                         | 185                         | 199                             | 274                         |
| 1.60       | 43                          | 85                              | 140                         | 154                         | 191                         | 206                             | 282                         |
| 1.65       | 45                          | 88                              | 144                         | 158                         | 197                         | 212                             | 291                         |
| 1.70       | 46                          | 91                              | 148                         | 163                         | 203                         | 218                             | 300                         |
| 1.75       | 48                          | 93                              | 153                         | 168                         | 209                         | 225                             | 309                         |
| 1.80       | 49                          | 96                              | 157                         | 173                         | 215                         | 231                             | 318                         |
| 1.85       | 50                          | 99                              | 162                         | 177                         | 221                         | 238                             | 326                         |
| 1.90       | 52                          | 101                             | 166                         | 182                         | 227                         | 244                             | 335                         |
| 1.95       | 53                          | 104                             | 170                         | 187                         | 233                         | 250                             | 344                         |
| 2.00       | 54                          | 107                             | 175                         | 192                         | 239                         | 257                             | 353                         |

## NOTE.

The values given in the table are expressed as units in the fifth decimal place.

To convert the specific gravity of a substance to the density at the same temperature the amount given in the table opposite to the specific gravity in question must be *subtracted* from the specific gravity.

*Example.* The specific gravity of a liquid at 60°F. relative to water at 60°F. as unity is 1.32672.

In the table under  $S_{\substack{60^{\circ}\text{F.} \\ 60^{\circ}\text{F.}}}$  and opposite to 1.30 we find 125, and opposite to 1.35 we find 130; hence by inspection the correction for 1.32672 is 128.

The density of the liquid in gms. per millilitre at 60°F. is hence 1.32672 - 0.00128, i.e. 1.32544 gms./ml.



## DENSITY OF WATER IN GRAMMES PER MILLILITRE \*

From 0°C. to 41°C.

| °C. | 0.0       | 0.1  | 0.2  | 0.3  | 0.4  | 0.5  | 0.6  | 0.7  | 0.8  | 0.9  |
|-----|-----------|------|------|------|------|------|------|------|------|------|
|     | 0.9998681 | 8747 | 8812 | 8875 | 8936 | 8996 | 9053 | 9109 | 9163 | 9216 |
| 1   | 9267      | 9315 | 9363 | 9408 | 9452 | 9494 | 9534 | 9573 | 9610 | 9645 |
| 2   | 9679      | 9711 | 9741 | 9769 | 9796 | 9821 | 9844 | 9866 | 9887 | 9905 |
| 3   | 9922      | 9937 | 9951 | 9962 | 9973 | 9981 | 9988 | 9994 | 9998 | 0000 |
| 4   | 1.0000000 | 9999 | 9996 | 9992 | 9986 | 9979 | 9970 | 9960 | 9947 | 9934 |
| 5   | 0.9999919 | 9902 | 9884 | 9864 | 9842 | 9819 | 9795 | 9769 | 9742 | 9713 |
| 6   | 9682      | 9650 | 9617 | 9582 | 9545 | 9507 | 9468 | 9427 | 9385 | 9341 |
| 7   | 9296      | 9249 | 9201 | 9151 | 9100 | 9048 | 8994 | 8938 | 8881 | 8823 |
| 8   | 8764      | 8703 | 8641 | 8577 | 8512 | 8445 | 8377 | 8308 | 8237 | 8165 |
| 9   | 8091      | 8017 | 7940 | 7863 | 7784 | 7704 | 7622 | 7539 | 7455 | 7369 |
| 10  | 7282      | 7194 | 7105 | 7014 | 6921 | 6826 | 6729 | 6632 | 6533 | 6432 |
| 11  | 6331      | 6228 | 6124 | 6020 | 5913 | 5805 | 5696 | 5586 | 5474 | 5362 |
| 12  | 5248      | 5132 | 5016 | 4898 | 4780 | 4660 | 4538 | 4415 | 4291 | 4166 |
| 13  | 4040      | 3912 | 3784 | 3654 | 3523 | 3391 | 3257 | 3122 | 2986 | 2850 |
| 14  | 2712      | 2572 | 2431 | 2289 | 2147 | 2003 | 1858 | 1711 | 1564 | 1416 |
| 15  | 1266      | 1114 | 0962 | 0809 | 0655 | 0499 | 0343 | 0185 | 0026 | 9865 |
| 16  | 0.9989705 | 9542 | 9378 | 9214 | 9048 | 8881 | 8713 | 8544 | 8373 | 8202 |
| 17  | 8029      | 7856 | 7681 | 7505 | 7328 | 7150 | 6971 | 6791 | 6610 | 6427 |
| 18  | 6244      | 6058 | 5873 | 5686 | 5498 | 5309 | 5119 | 4927 | 4735 | 4541 |
| 19  | 4347      | 4152 | 3955 | 3757 | 3558 | 3358 | 3158 | 2955 | 2752 | 2549 |
| 20  | 2343      | 2137 | 1930 | 1722 | 1511 | 1301 | 1090 | 0878 | 0663 | 0449 |
| 21  | 0233      | 0016 | 9799 | 9580 | 9359 | 9139 | 8917 | 8694 | 8470 | 8245 |
| 22  | 0.9978019 | 7792 | 7564 | 7335 | 7104 | 6873 | 6641 | 6408 | 6173 | 5938 |
| 23  | 5702      | 5466 | 5227 | 4988 | 4747 | 4506 | 4264 | 4021 | 3777 | 3531 |
| 24  | 3286      | 3039 | 2790 | 2541 | 2291 | 2040 | 1788 | 1535 | 1280 | 1026 |
| 25  | 0770      | 0513 | 0255 | 9997 | 9736 | 9476 | 9214 | 8951 | 8688 | 8423 |
| 26  | 0.9968158 | 7892 | 7624 | 7356 | 7087 | 6817 | 6545 | 6273 | 6000 | 5726 |
| 27  | 5451      | 5176 | 4898 | 4620 | 4342 | 4062 | 3782 | 3500 | 3218 | 2935 |
| 28  | 2652      | 2366 | 2080 | 1793 | 1505 | 1217 | 0928 | 0637 | 0346 | 0053 |
| 29  | 0.9959761 | 9466 | 9171 | 8876 | 8579 | 8282 | 7983 | 7684 | 7383 | 7083 |
| 30  | 6780      | 6478 | 6174 | 5869 | 5564 | 5258 | 4950 | 4642 | 4334 | 4024 |
| 31  | 3714      | 3401 | 3089 | 2776 | 2462 | 2147 | 1832 | 1515 | 1198 | 0880 |
| 32  | 0561      | 0241 | 9920 | 9599 | 9276 | 8954 | 8630 | 8304 | 7979 | 7653 |
| 33  | 0.9947325 | 6997 | 6668 | 6338 | 6007 | 5676 | 5345 | 5011 | 4678 | 4343 |
| 34  | 4007      | 3671 | 3335 | 2997 | 2659 | 2318 | 1978 | 1638 | 1296 | 0953 |
| 35  | 0610      | 0267 | 9922 | 9576 | 9230 | 8883 | 8534 | 8186 | 7837 | 7486 |
| 36  | 0.9937136 | 6784 | 6432 | 6078 | 5725 | 5369 | 5014 | 4658 | 4301 | 3943 |
| 37  | 3585      | 3226 | 2866 | 2505 | 2144 | 1782 | 1419 | 1055 | 0691 | 0326 |
| 38  | 0.9929960 | 9593 | 9227 | 8859 | 8490 | 8120 | 7751 | 7380 | 7008 | 6636 |
| 39  | 6263      | 5890 | 5516 | 5140 | 4765 | 4389 | 4011 | 3634 | 3255 | 2876 |
| 40  | 2497      | 2116 | 1734 | 1352 | 0971 | 0587 | 0203 | 9818 | 9433 | 9047 |
| 41  | 0.9918661 |      |      |      |      |      |      |      |      |      |

\* P. Chappuis' "*Travaux et Mémoires.*" D. 40. Tome xiii. 1907



DENSITY OF WATER IN GRAMMES PER MILLILITRE FROM  
40°C. TO 100°C.\*

| °C. | 0       | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   |
|-----|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 40  | 0.99224 | 186 | 147 | 107 | 066 | 024 | 982 | 940 | 896 | 852 |
| 50  | 0.98807 | 762 | 715 | 669 | 621 | 573 | 525 | 475 | 425 | 375 |
| 60  | 324     | 272 | 220 | 167 | 113 | 059 | 005 | 950 | 894 | 838 |
| 70  | 0.97781 | 723 | 665 | 607 | 548 | 489 | 429 | 368 | 307 | 245 |
| 80  | 183     | 120 | 057 | 994 | 930 | 865 | 800 | 734 | 668 | 601 |
| 90  | 0.96534 | 467 | 399 | 330 | 261 | 192 | 122 | 051 | 981 | 909 |
| 100 | 0.95838 |     |     |     |     |     |     |     |     |     |

\* M. Thiesen. *Wiss. Abhand. Phys.-Tech. Reich.* Vol. iv, Part 1, p. 32, 1904.

Density of Mercury in gms. per c.c. from  
—20°C. to 360°C.

| °C. | D.      | °C. | D.      | °C. | D.      |
|-----|---------|-----|---------|-----|---------|
| -20 | 13.6199 | 110 | 13.3274 | 240 | 13.0173 |
| -10 | 13.6446 | 120 | 13.3034 | 250 | 12.9935 |
| 0   | 13.5952 | 130 | 13.2794 | 260 | 12.9697 |
| 10  | 13.5705 | 140 | 13.2554 | 270 | 12.9459 |
| 20  | 13.5459 | 150 | 13.2315 | 280 | 12.9221 |
| 30  | 13.5214 | 160 | 13.2076 | 290 | 12.8982 |
| 40  | 13.4970 | 170 | 13.1838 | 300 | 12.8743 |
| 50  | 13.4726 | 180 | 13.1600 | 310 | 12.8504 |
| 60  | 13.4483 | 190 | 13.1362 | 320 | 12.8265 |
| 70  | 13.4240 | 200 | 13.1124 | 330 | 12.8024 |
| 80  | 13.3998 | 210 | 13.0886 | 340 | 12.7784 |
| 90  | 13.3756 | 220 | 13.0648 | 350 | 12.7543 |
| 100 | 13.3515 | 230 | 13.0410 | 360 | 12.7301 |

This and the following tables are based on determinations of the density of mercury at 0°C. by Marek, 1883, and by Thiesen and Scheele, 1897, and the expansion formula given by Donaldson, 1913.

# Density of Mercury in gms. per c.c. from 0°C. to 40°C.

| °C. | 0.0     | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|-----|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0   | 13.5952 | 49  | 47  | 44  | 42  | 39  | 37  | 34  | 32  | 29  |
| 1   | 13.5927 | 24  | 22  | 19  | 17  | 15  | 12  | 10  | 07  | 05  |
| 2   | 13.5902 | 00  | 97* | 95* | 92* | 90* | 87* | 85* | 82* | 80* |
| 3   | 13.5878 | 75  | 73  | 70  | 68  | 65  | 63  | 60  | 58  | 55  |
| 4   | 13.5853 | 50  | 48  | 46  | 43  | 41  | 38  | 36  | 33  | 31  |
| 5   | 13.5828 | 26  | 23  | 21  | 18  | 16  | 13  | 11  | 09  | 06  |
| 6   | 13.5804 | 01  | 99* | 96* | 94* | 91* | 89* | 86* | 84* | 82* |
| 7   | 13.5779 | 77  | 74  | 72  | 69  | 67  | 64  | 62  | 59  | 57  |
| 8   | 13.5754 | 52  | 50  | 47  | 45  | 42  | 40  | 37  | 35  | 32  |
| 9   | 13.5730 | 27  | 25  | 22  | 20  | 17  | 15  | 13  | 10  | 08  |
| 10  | 13.5705 | 03  | 00  | 98* | 95* | 93* | 90* | 88* | 85* | 83* |
| 11  | 13.5681 | 78  | 76  | 73  | 71  | 68  | 66  | 63  | 61  | 58  |
| 12  | 13.5656 | 53  | 51  | 49  | 46  | 44  | 41  | 39  | 36  | 34  |
| 13  | 13.5631 | 29  | 26  | 24  | 22  | 19  | 17  | 14  | 12  | 09  |
| 14  | 13.5607 | 04  | 02  | 99* | 97* | 95* | 92* | 90* | 87* | 85* |
| 15  | 13.5582 | 80  | 77  | 75  | 72  | 70  | 67  | 65  | 63  | 60  |
| 16  | 13.5558 | 55  | 53  | 50  | 48  | 45  | 43  | 41  | 38  | 36  |
| 17  | 13.5533 | 31  | 28  | 26  | 23  | 21  | 18  | 16  | 13  | 11  |
| 18  | 13.5509 | 06  | 04  | 01  | 99* | 96* | 94* | 91* | 89* | 86* |
| 19  | 13.5484 | 82  | 79  | 77  | 74  | 72  | 69  | 67  | 64  | 62  |
| 20  | 13.5459 | 57  | 55  | 52  | 50  | 47  | 45  | 42  | 40  | 37  |
| 21  | 13.5435 | 32  | 30  | 28  | 25  | 23  | 20  | 18  | 15  | 13  |
| 22  | 13.5410 | 08  | 05  | 03  | 01  | 98* | 96* | 93* | 91* | 88* |
| 23  | 13.5386 | 83  | 81  | 79  | 76  | 74  | 71  | 69  | 66  | 64  |
| 24  | 13.5361 | 59  | 56  | 54  | 52  | 49  | 47  | 44  | 42  | 39  |
| 25  | 13.5337 | 34  | 32  | 30  | 27  | 25  | 22  | 20  | 17  | 15  |
| 26  | 13.5312 | 10  | 07  | 05  | 03  | 00  | 98* | 95* | 93* | 90* |
| 27  | 13.5288 | 85  | 83  | 81  | 78  | 76  | 73  | 71  | 68  | 66  |
| 28  | 13.5263 | 61  | 58  | 56  | 54  | 51  | 49  | 46  | 44  | 41  |
| 29  | 13.5239 | 36  | 34  | 32  | 29  | 27  | 24  | 22  | 19  | 17  |
| 30  | 13.5214 | 12  | 09  | 07  | 05  | 02  | 00  | 97* | 95* | 92* |
| 31  | 13.5190 | 87  | 85  | 83  | 80  | 78  | 75  | 73  | 70  | 68  |
| 32  | 13.5165 | 63  | 60  | 58  | 56  | 53  | 51  | 48  | 46  | 43  |
| 33  | 13.5141 | 39  | 36  | 34  | 31  | 29  | 26  | 24  | 21  | 19  |
| 34  | 13.5116 | 14  | 12  | 09  | 07  | 04  | 02  | 99* | 97* | 94* |
| 35  | 13.5092 | 90  | 87  | 85  | 82  | 80  | 77  | 75  | 72  | 70  |
| 36  | 13.5068 | 65  | 63  | 60  | 58  | 55  | 53  | 50  | 48  | 46  |
| 37  | 13.5043 | 41  | 38  | 36  | 33  | 31  | 28  | 26  | 24  | 21  |
| 38  | 13.5019 | 16  | 14  | 11  | 09  | 06  | 04  | 02  | 99* | 97  |
| 39  | 13.4994 | 91  | 89  | 87  | 84  | 82  | 80  | 77  | 75  | 72  |
| 40  | 13.4970 | 67  | 65  | 63  | 60  | 58  | 55  | 53  | 50  | 48  |

## DENSITIES OF METALS.

The values given are in gms. per cc. at the ordinary room temperature unless otherwise stated.

Density  $\times 62.335 =$  lbs. per c. ft.

|   |   |   |   |   |   |   |           |
|---|---|---|---|---|---|---|-----------|
| <i>Aluminium</i>                        | - | - | - | - | - | - | 2.70      |
| Commercial wrought, 2.67; cast,         | - | - | - | - | - | - | 2.56      |
| Wire (free from $\text{SiO}_2$ )        | - | - | - | - | - | - | 2.70      |
| Pure                                    | - | - | - | - | - | - | 2.58      |
| Liquid at M.P. ( $720^\circ\text{C}.$ ) | - | - | - | - | - | - | 2.43      |
| <i>Antimony</i>                         | - | - | - | - | - | - | 6.62      |
| Distilled in vacuo                      | - | - | - | - | - | - | 6.62      |
| " " and compressed                      | - | - | - | - | - | - | 6.69      |
| Amorphous                               | - | - | - | - | - | - | 6.22      |
| Liquid at M.P. ( $620^\circ\text{C}.$ ) | - | - | - | - | - | - | 6.41      |
| <i>Arsenic</i>                          | - | - | - | - | - | - | 5.72      |
| Crystalline, grey, 5.72; black,         | - | - | - | - | - | - | 4.64      |
| Amorphous, brown                        | - | - | - | - | - | - | 3.70      |
| <i>Bismuth</i>                          | - | - | - | - | - | - | 9.80      |
| Distilled in vacuo                      | - | - | - | - | - | - | 9.78      |
| Electrolytic                            | - | - | - | - | - | - | 9.75      |
| Wire                                    | - | - | - | - | - | - | 9.85      |
| Solid at M.P. ( $271^\circ\text{C}.$ )  | - | - | - | - | - | - | 9.67      |
| Liquid " "                              | - | - | - | - | - | - | 10.00     |
| <i>Cadmium</i>                          | - | - | - | - | - | - | 8.64      |
| Rolled                                  | - | - | - | - | - | - | 8.66      |
| Distilled in vacuo                      | - | - | - | - | - | - | 8.65      |
| Wire, cold drawn                        | - | - | - | - | - | - | 8.64      |
| Solid at M.P. ( $318^\circ\text{C}.$ )  | - | - | - | - | - | - | 8.37      |
| Liquid " "                              | - | - | - | - | - | - | 7.99      |
| <i>Copper</i>                           | - | - | - | - | - | - | 8.93      |
| Cast                                    | - | - | - | - | - | - | 8.30—8.92 |
| Wire                                    | - | - | - | - | - | - | 8.93—8.95 |
| Beaten                                  | - | - | - | - | - | - | 8.92—8.96 |
| Electrolytic                            | - | - | - | - | - | - | 8.88—8.95 |
| Distilled in vacuo                      | - | - | - | - | - | - | 8.93      |
| <i>Gold</i>                             | - | - | - | - | - | - | 19.3      |
| Cast                                    | - | - | - | - | - | - | 19.29     |
| Rolled                                  | - | - | - | - | - | - | 19.31     |
| Wire: soft drawn, 19.26; hard drawn,    | - | - | - | - | - | - | 19.25     |
| Crystalline from solution               | - | - | - | - | - | - | 19.43     |
| <i>Iron</i>                             | - | - | - | - | - | - | 7.86      |
| Pure                                    | - | - | - | - | - | - | 7.85—7.88 |
| Wrought                                 | - | - | - | - | - | - | 7.79—7.85 |
| Cast: grey, 7.03—7.13; white,           | - | - | - | - | - | - | 7.58—7.73 |
| Piano wire, 7.78; annealed,             | - | - | - | - | - | - | 7.80      |

DENSITIES OF METALS (*contd.*).

|                                    |   |   |   |   |   |   |       |       |
|------------------------------------|---|---|---|---|---|---|-------|-------|
| <i>Lead</i>                        | - | - | - | - | - | - | -     | 11·34 |
| Cast                               | - | - | - | - | - | - | -     | 11·34 |
| Rolled                             | - | - | - | - | - | - | -     | 11·35 |
| Wire                               | - | - | - | - | - | - | -     | 11·34 |
| Distilled in vacuo                 | - | - | - | - | - | - | -     | 11·34 |
| Solid at M.P. (325°C.)             | - | - | - | - | - | - | -     | 11·01 |
| Liquid                             | " | " | - | - | - | - | -     | 10·65 |
| <i>Nickel</i>                      | - | - | - | - | - | - | -     | 8·8   |
| Cast                               | - | - | - | - | - | - | -     | 8·90  |
| Malleable, sheets, etc.            | - | - | - | - | - | - | -     | 8·84  |
| Wire, cold drawn                   | - | - | - | - | - | - | -     | 8·76  |
| " " " annealed                     | - | - | - | - | - | - | -     | 8·84  |
| <i>Platinum</i>                    | - | - | - | - | - | - | -     | 21·4  |
| Pure, cast and beaten              | - | - | - | - | - | - | -     | 21·4  |
| Wire, cold drawn                   | - | - | - | - | - | - | -     | 21·4  |
| Platinum sponge                    | - | - | - | - | - | - | -     | 21·2  |
| <i>Silver</i>                      | - | - | - | - | - | - | -     | 10·50 |
| Cast                               | - | - | - | - | - | - | 10·42 | 10·51 |
| Commercial, pure                   | - | - | - | - | - | - | -     | 10·36 |
| Electrolytic                       | - | - | - | - | - | - | -     | 10·53 |
| <i>Tin</i>                         | - | - | - | - | - | - | -     | 7·28  |
| Commercial Tin (white Tetragonal). | - | - | - | - | - | - | -     |       |
| Cast                               | - | - | - | - | - | - | 7·28  | 7·30  |
| Solid at M.P. (226°C.)             | - | - | - | - | - | - | -     | 7·18  |
| Liquid                             | " | " | - | - | - | - | -     | 6·99  |
| Rhombic modification               | - | - | - | - | - | - | -     | 6·56  |
| Grey modification                  | - | - | - | - | - | - | 5·75  | 5·85  |
| <i>Zinc</i>                        | - | - | - | - | - | - | -     | 7·1   |
| Cast, cooled slowly                | - | - | - | - | - | - | 7·10  | 7·16  |
| " cooled quickly                   | - | - | - | - | - | - | 7·04  | 7·14  |
| Rolled                             | - | - | - | - | - | - | -     | 7·19  |
| Distilled in vacuo                 | - | - | - | - | - | - | -     | 6·92  |
| " " and compressed                 | - | - | - | - | - | - | -     | 7·13  |

## DENSITIES OF ALLOYS.

The values given below are in gms. per cc. at ordinary temperatures. Compositions are percentage by weight.

|                                    |   |   |   |   |   |   |   |      |
|------------------------------------|---|---|---|---|---|---|---|------|
| Brass, Yellow, 70 Cu + 30 Zn, cast | - | - | - | - | - | - | - | 8·44 |
| " " " " rolled                     | - | - | - | - | - | - | - | 8·56 |
| " " " " drawn                      | - | - | - | - | - | - | - | 8·70 |
| " Red, 90 Cu + 10 Zn               | - | - | - | - | - | - | - | 8·60 |
| " White, 50 Cu + 50 Zn             | - | - | - | - | - | - | - | 8·20 |
| Bronze, 90 Cu + 10 Sn              | - | - | - | - | - | - | - | 8·78 |
| " 85 Cu + 15 Sn                    | - | - | - | - | - | - | - | 8·89 |
| " 80 Cu + 20 Sn                    | - | - | - | - | - | - | - | 8·74 |
| " 75 Cu + 25 Sn                    | - | - | - | - | - | - | - | 8·83 |

DENSITIES OF ALLOYS (*contd.*).

|   |       |
|---|-------|
| German Silver, 26.3 Cu + 36.6 Zn + 36.8 Ni                      | 8.30  |
| " " 52 Cu + 26 Zn + 22 Ni                                       | 8.45  |
| " " 59 Cu + 30 Zn + 11 Ni                                       | 8.34  |
| " " 63 Cu + 30 Zn + 6 Ni  | 8.30  |
| Monel Metal   | 8.80  |
| Copper and Aluminium, 97 Cu + 3 Al                              | 8.69  |
| " " 95 Cu + 5 Al  | 8.37  |
| " " 90 Cu + 10 Al   | 7.69  |
| Aluminium and Zinc, 91 Al + 9 Zn                                | 2.80  |
| Wood's Metal, 50 Bi + 25 Pb + 12.5 Cd + 12.5 Sn                 | 9.70  |
| Bismuth, Lead and Tin, 53 Bi + 40 Pb + 7 Sn                     | 10.56 |
| Antimony and Bismuth, 54 Sb + 46 Bi                             | 7.86  |
| Antimony and Tin, 51.4 Sb + 48.6 Sn                             | 11.46 |
| " " 9.5 Sb + 90.5 Sn  | 9.36  |
| Iron and Silicon (Durion), 84.5 Fe + 14 Si + 1.5 other Elements | 7.00  |
| Iron and Antimony, 55 Fe + 45 Sb                                | 8.16  |
| Tin and Cadmium, 68 Sn + 32 Cd                                  | 7.70  |
| Lead and Tin, 87.5 Pb + 12.5 Sn                                 | 10.60 |
| " " 84 Pb + 16 Sn   | 10.33 |
| " " 77.8 Pb + 22.2 Sn   | 10.05 |
| " " 63.7 Pb + 36.3 Sn   | 9.43  |
| " " 46.7 Pb + 53.3 Sn   | 8.73  |
| " " 30.5 Pb + 69.5 Sn   | 8.24  |
| Lead and Mercury, 51 Pb + 49 Hg                                 | 12.48 |
| Mercury and Tin, 77.5 Hg + 22.5 Sn                              | 11.46 |
| " " 46.3 Hg + 53.7 Sn   | 9.36  |
| Silver and Lead, 51 Ag + 49 Pb                                  | 10.92 |
| " " 2 Ag + 98 Pb  | 11.33 |
| Silver and Copper, 94.4 Ag + 5.6 Cu                             | 10.36 |
| " " 89.3 Ag + 10.7 Cu   | 10.30 |
| " " 66.3 Ag + 33.7 Cu   | 10.00 |
| " " 49.65 Ag + 50.35 Cu   | 9.65  |
| " " 29.5 Ag + 70.5 Cu   | 9.32  |
| Gold and Silver, 78.5 Au + 21.5 Ag                              | 16.35 |
| " " 64.6 Au + 35.4 Ag   | 14.87 |
| " " 47.7 Au + 52.3 Ag   | 13.43 |
| " " 23.5 Au + 76.5 Ag   | 11.76 |
| Gold and Copper, 98 Au + 2 Cu                                   | 18.84 |
| " " 96 Au + 4 Cu  | 18.36 |
| " " 94 Au + 6 Cu  | 17.95 |
| " " 92 Au + 8 Cu  | 17.52 |
| Gold and Lead, 8.7 Au + 91.3 Pb                                 | 11.84 |
| Platinum and Iridium, 90 Pt + 10 Ir                             | 21.62 |
| " " 85 Pt + 15 Ir   | 21.62 |
| " " 66.7 Pt + 33.3 Ir   | 21.87 |
| " " 5 Pt + 95 Ir  | 22.38 |

## DENSITIES OF VARIOUS SUBSTANCES.

The values given below are approximate densities in gms. per cc. at ordinary room temperature.

Density  $\times 62.335$  = lbs. per c. ft.

|                               |         |                                |         |
|-------------------------------|---------|--------------------------------|---------|
| Asbestos .....                | 2.1—2.8 | Leather .....                  | 0.9—1.0 |
| „ board .....                 | 1.2     | Loam .....                     | 1.5—2.3 |
| Basalt .....                  | 2.7—3.2 | Marble .....                   | 2.5—2.8 |
| Bone .....                    | 1.7—2.0 | Marl .....                     | 2.3—2.5 |
| Brickwork .....               | 1.5—1.7 | Masonry .....                  | 2.4     |
| Celluloid .....               | 1.4     | Methylated Spirit .....        | 0.8     |
| Cement .....                  | 2.7—3.0 | Milk .....                     | 1.03    |
| Charcoal (wood) .....         | 0.3—0.6 | Mortar (lime) apparent .....   | 1.8     |
| Coke (absolute density) ..... | 1.4     | Paper .....                    | 0.7—1.1 |
| „ (apparent) „ .....          | 0.5     | Paraffin Wax .....             | 0.8—0.9 |
| Cork .....                    | 0.2     | Pitch .....                    | 1.1     |
| Cotton (air dried) .....      | 1.5     | Porcelain .....                | 2.2—2.5 |
| Ebonite .....                 | 1.2     | Pumice, natural .....          | 0.4—0.9 |
| Fire Brick .....              | 1.8—2.2 | Resin (pine) .....             | 1.1     |
| Flax (air dried) .....        | 1.5     | Sand-dry absolute .....        | 1.5     |
| Gas Carbon .....              | 1.8—2.0 | „ apparent .....               | 2.6     |
| Gelatine .....                | 1.3     | Sandstone .....                | 2.2—2.5 |
| Glass, Bottle .....           | 2.6—2.7 | „ artificial .....             | 2.0     |
| Crown ordinary .....          | 2.4     | Sea-water .....                | 1.03    |
| Crystal „ .....               | 3.3     | Silica fused transparent ..... | 2.2     |
| Flint .....                   | 2.9—3.4 | „ „ translucent .....          | 2.1     |
| Plate .....                   | 2.5     | Silk, natural .....            | 1.6     |
| Window .....                  | 2.5     | Slag .....                     | 2.5—3.0 |
| Glue .....                    | 1.3     | Slaked lime, apparent .....    | 1.3—1.4 |
| Granite .....                 | 2.5—3.0 | Slate .....                    | 2.6—2.7 |
| Gum arabic .....              | 1.3—1.4 | Steel .....                    | 7.8—7.9 |
| Gutta Percha .....            | 1.0     | Tile .....                     | 1.8     |
| India Rubber, raw .....       | 0.9—1.0 | Turpentine .....               | 0.9     |
| „ „ vulcanised .....          | 1.2—1.7 | Vinegar .....                  | 1.1     |
| Ivory .....                   | 1.8—1.9 | Wool (air dried) .....         | 1.3     |

### *Seasoned woods:*

|               |         |                     |         |
|---------------|---------|---------------------|---------|
| Alder .....   | 0.5     | Lignum-vitæ .....   | 1.2—1.4 |
| Ash .....     | 0.7—0.8 | Mahogany .....      | 0.6—0.8 |
| Bamboo .....  | 0.4     | Maple .....         | 0.7     |
| Beech .....   | 0.7     | Oak .....           | 0.7—1.0 |
| Birch .....   | 0.7     | Pine (white) .....  | 0.5—0.6 |
| Cedar .....   | 0.5—0.7 | Pine (yellow) ..... | 0.5—0.8 |
| Cypress ..... | 0.5     | Poplar .....        | 0.4—0.5 |
| Ebony .....   | 1.2     | Teak .....          | 0.8—0.9 |
| Elm .....     | 0.6—0.7 | Walnut .....        | 0.7     |
| Larch .....   | 0.5     | Willow .....        | 0.5—0.6 |

# SPECIFIC GRAVITIES AND DENSITIES OF SOLUTIONS.

## Density of Aqueous Solutions of Acetic Acid.

(Oudemans, *Zs. f. Chemie*, 1866.)

$g\%$  = gms. of acid in 100 grms. of solution

| $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|-------|--|-------|--|-------|--|-------|--|
| 1     | 1.0007   | 26    | 1.0363   | 51    | 1.0623   | 76    | 1.0747   |
| 2     | 022  | 27    | 375  | 52    | 631  | 77    | 748  |
| 3     | 037  | 28    | 388  | 53    | 638  | 78    | 748  |
| 4     | 052  | 29    | 400  | 54    | 646  | 79    | 748  |
| 5     | 067  | 30    | 412  | 55    | 653  | 80    | 748  |
| 6     | 083  | 31    | 424  | 56    | 660  | 81    | 747  |
| 7     | 098  | 32    | 436  | 57    | 666  | 82    | 746  |
| 8     | 113  | 33    | 447  | 58    | 673  | 83    | 744  |
| 9     | 127  | 34    | 459  | 59    | 679  | 84    | 742  |
| 10    | 142  | 35    | 470  | 60    | 685  | 85    | 739  |
| 11    | 157  | 36    | 481  | 61    | 691  | 86    | 736  |
| 12    | 171  | 37    | 492  | 62    | 697  | 87    | 731  |
| 13    | 185  | 38    | 502  | 63    | 702  | 88    | 726  |
| 14    | 200  | 39    | 513  | 64    | 707  | 89    | 720  |
| 15    | 214  | 40    | 523  | 65    | 712  | 90    | 713  |
| 16    | 228  | 41    | 533  | 66    | 717  | 91    | 705  |
| 17    | 242  | 42    | 543  | 67    | 721  | 92    | 696  |
| 18    | 256  | 43    | 552  | 68    | 725  | 93    | 686  |
| 19    | 270  | 44    | 562  | 69    | 729  | 94    | 674  |
| 20    | 284  | 45    | 571  | 70    | 733  | 95    | 660  |
| 21    | 298  | 46    | 580  | 71    | 737  | 96    | 644  |
| 22    | 311  | 47    | 589  | 72    | 740  | 97    | 625  |
| 23    | 324  | 48    | 598  | 73    | 742  | 98    | 604  |
| 24    | 337  | 49    | 607  | 74    | 744  | 99    | 580  |
| 25    | 350  | 50    | 615  | 75    | 746  | 100   | 553  |

Note that the specific gravity attains a maximum in the neighbourhood of 80% of acid.

## Density of Mixtures of Ethyl Alcohol and Water at Various Temperatures.

The whole of the following tables relating to mixtures of ethyl alcohol and water are based on the results obtained at the Bureau of Standards, Washington. See *Bulletin of the Bureau of Standards*, Vol. 9, No. 3; and *Circular of the Bureau of Standards*, No. 19, 1916. For excise purposes in England, the table in the "Spirits" section is used.

$g\%$  = weight of alcohol in 100 gms. of mixture.

| $g\%$ | $S_{\frac{10^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{20^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{25^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{30^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{35^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{40^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|-------|--|--|--|--|--|--|--|
| 0     | 0.99973  | 0.99913  | 0.99823  | 0.99708  | 0.99568  | 0.99406  | 0.99225  |
| 1     | 785  | 725  | 636  | 520  | 379  | 217  | 034  |
| 2     | 602  | 542  | 453  | 336  | 194  | 031  | .98846   |
| 3     | 426  | 365  | 275  | 157  | 014  | .98849   | 663  |
| 4     | 258  | 195  | 103  | .98984   | .98839   | 672  | 485  |
| 5     | 098  | 032  | .98938   | 817  | 670  | 501  | 311  |
| 6     | .98946   | .98877   | 780  | 656  | 507  | 335  | 142  |
| 7     | 801  | 729  | 627  | 500  | 347  | 172  | .97975   |
| 8     | 660  | 584  | 478  | 346  | 189  | 009  | 808  |
| 9     | 524  | 442  | 331  | 193  | 031  | .97846   | 641  |
| 10    | 393  | 304  | 187  | 043  | .97875   | 685  | 475  |
| 11    | 267  | 171  | 047  | .97897   | 723  | 527  | 312  |
| 12    | 145  | 041  | .97910   | 753  | 573  | 371  | 150  |
| 13    | 026  | .97914   | 775  | 611  | 424  | 216  | .96989   |
| 14    | .97911   | 790  | 643  | 472  | 278  | 063  | 829  |
| 15    | 800  | 669  | 514  | 334  | 133  | .96911   | 670  |
| 16    | 692  | 552  | 387  | 199  | .96990   | 760  | 512  |
| 17    | 583  | 433  | 259  | 062  | 844  | 607  | 352  |
| 18    | 473  | 313  | 129  | .96923   | 697  | 452  | 189  |
| 19    | 363  | 191  | .96997   | 782  | 547  | 294  | 023  |
| 20    | 252  | 068  | 864  | 639  | 395  | 134  | .95856   |
| 21    | 139  | .96944   | 729  | 495  | 242  | .95973   | 687  |
| 22    | 024  | 818  | 592  | 348  | 087  | 809  | 516  |
| 23    | .96907   | 689  | 453  | 199  | .95929   | 643  | 343  |
| 24    | 787  | 558  | 312  | 048  | 769  | 476  | 168  |
| 25    | 665  | 424  | 168  | .95895   | 607  | 306  | .94991   |
| 26    | 539  | 287  | 020  | 738  | 442  | 133  | 810  |
| 27    | 406  | 144  | .95867   | 576  | 272  | .94955   | 625  |
| 28    | 268  | .95996   | 710  | 410  | 098  | 774  | 438  |



$g\%$  = weight of alcohol in 100 gms. of mixture.

| $g\%$ | $S_{\frac{10^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{20^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{25^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{30^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{35^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{40^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|-------|--|--|--|--|--|--|--|
| 29    | .96125   | .95844   | .95548   | .95241   | .94922   | .94590   | .94248   |
| 30    | .95977   | 686  | 382  | 067  | 741  | 403  | 055  |
| 31    | 823  | 526  | 212  | .94890   | 557  | 214  | .93860   |
| 32    | 665  | 357  | 038  | 709  | 370  | 021  | 662  |
| 33    | 502  | 186  | .94860   | 525  | 180  | .93825   | 461  |
| 34    | 334  | 011  | 679  | 337  | .93986   | 626  | 257  |
| 35    | 162  | .94832   | 494  | 146  | 790  | 425  | 051  |
| 36    | .94986   | 650  | 306  | .93952   | 591  | 221  | .92843   |
| 37    | 805  | 464  | 114  | 756  | 390  | 016  | 634  |
| 38    | 620  | 273  | .93919   | 556  | 186  | .92808   | 422  |
| 39    | 431  | 079  | 720  | 353  | .92979   | 597  | 208  |
| 40    | 238  | .93882   | 518  | 148  | 770  | 385  | .91992   |
| 41    | 042  | 682  | 314  | .92940   | 558  | 170  | 774  |
| 42    | .93842   | 478  | 107  | 729  | 344  | .91952   | 554  |
| 43    | 639  | 271  | .92897   | 516  | 128  | 733  | 332  |
| 44    | 433  | 062  | 685  | 301  | .91910   | 513  | 108  |
| 45    | 226  | .92852   | 472  | 085  | 692  | 291  | .90884   |
| 46    | 017  | 640  | 257  | .91868   | 472  | 069  | 660  |
| 47    | .92806   | 426  | 041  | 649  | 250  | .90845   | 434  |
| 48    | 593  | 211  | .91823   | 429  | 028  | 621  | 207  |
| 49    | 379  | .91995   | 604  | 208  | .90805   | 396  | .89979   |
| 50    | 162  | 776  | 384  | .90985   | 580  | 168  | 750  |
| 51    | .91943   | 555  | 160  | 760  | 353  | 89940  | 519  |
| 52    | 723  | 333  | .90936   | 534  | 125  | 710  | 288  |
| 53    | 502  | 110  | 711  | 307  | .89896   | 479  | 056  |
| 54    | 279  | .90885   | 485  | 079  | 667  | 248  | .88823   |
| 55    | 055  | 659  | 258  | .89850   | 437  | 016  | 589  |
| 56    | .90831   | 433  | 031  | 621  | 206  | .88784   | 356  |
| 57    | 607  | 207  | .89803   | 392  | .88975   | 552  | 122  |
| 58    | 381  | .89980   | 574  | 162  | 744  | 319  | .87888   |
| 59    | 154  | 752  | 344  | .88931   | 512  | 085  | 653  |
| 60    | .89927   | 523  | 113  | 699  | 278  | .87851   | 417  |
| 61    | 698  | 293  | .88882   | 466  | 044  | 615  | 180  |
| 62    | 468  | 062  | 650  | 233  | .87809   | 379  | .86943   |
| 63    | 237  | .88830   | 417  | .87998   | 574  | 142  | 705  |
| 64    | 006  | 597  | 183  | 763  | 337  | 86905  | 466  |

$g\%$  = weight of alcohol in 100 gms. of mixture.

| $g\%$ | $S_{\frac{10^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{20^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{25^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{30^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{35^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $S_{\frac{40^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|-------|--|--|--|--|--|--|--|
| 65    | .88774   | .88364   | .87948   | .87527   | .87100   | .86667   | .86227   |
| 66    | 541  | 130  | 713  | 291  | .86863   | 429  | .85987   |
| 67    | 308  | .87895   | 477  | 054  | 625  | 190  | 747  |
| 68    | 074  | 660  | 241  | .86817   | 387  | .85950   | 507  |
| 69    | .87839   | 424  | 004  | 579  | 148  | 710  | 266  |
| 70    | 602  | 187  | .86766   | 340  | .85908   | 470  | 025  |
| 71    | 365  | .86949   | 527  | 100  | 667  | 228  | .84783   |
| 72    | 127  | 710  | 287  | .85859   | 426  | .84986   | 540  |
| 73    | .86888   | 470  | 047  | 618  | 184  | 743  | 297  |
| 74    | 648  | 229  | .85806   | 376  | .84941   | 500  | 053  |
| 75    | 408  | .85988   | 564  | 134  | 698  | 257  | .83809   |
| 76    | 168  | 747  | 322  | .84891   | 455  | 013  | 564  |
| 77    | .85927   | 505  | 079  | 647  | 211  | .83768   | 319  |
| 78    | 685  | 262  | .84835   | 403  | .83966   | 523  | 074  |
| 79    | 442  | 018  | 590  | 158  | 720  | 277  | .82827   |
| 80    | 197  | .84772   | 344  | .83911   | 473  | 029  | 578  |
| 81    | .84950   | 525  | 096  | 664  | 224  | .82780   | 329  |
| 82    | 702  | 277  | .83846   | 415  | .82974   | 530  | 079  |
| 83    | 453  | 028  | 599  | 164  | 724  | 279  | .81828   |
| 84    | 203  | .83777   | 348  | .82913   | 473  | 027  | 576  |
| 85    | .83951   | 535  | 095  | 660  | 220  | .81774   | 322  |
| 86    | 697  | 271  | .82840   | 405  | .81965   | 519  | 067  |
| 87    | 441  | 014  | 583  | 148  | 708  | 262  | .80811   |
| 88    | 181  | .82754   | 323  | .81888   | 448  | 003  | 552  |
| 89    | .82919   | 492  | 062  | 626  | 186  | .80742   | 291  |
| 90    | 654  | 227  | .81797   | 362  | .80922   | 478  | 028  |
| 91    | 386  | .81959   | 529  | 094  | 655  | 211  | .79761   |
| 92    | 114  | 688  | 257  | .80823   | 384  | .79941   | 491  |
| 93    | .81839   | 413  | .80983   | 549  | 111  | 669  | 220  |
| 94    | 561  | 134  | 705  | 272  | .79835   | 393  | .78947   |
| 95    | 278  | .80852   | 424  | .79991   | 555  | 114  | 670  |
| 96    | .80991   | 566  | 138  | 706  | 271  | .78831   | 388  |
| 97    | 698  | 274  | .79846   | 415  | .78981   | 542  | 100  |
| 98    | 399  | .79975   | 547  | 117  | 684  | 247  | .77806   |
| 99    | 094  | 670  | 243  | .78814   | 382  | .77946   | 507  |
| 100   | .79784   | 360  | .78934   | 505  | 075  | 641  | 203  |

SPECIFIC GRAVITY AND COMPOSITION OF  
MIXTURES OF ETHYL ALCOHOL AND WATER  
AT 60°F.

V% = volume of alcohol in 100 cc. of mixture at 60° F.

g% = weight of alcohol in 100 gms. of mixture.

| V% | g%     | $S_{60^{\circ}\text{F.}}^{60^{\circ}\text{F.}}$ | V% | g%     | $S_{60^{\circ}\text{F.}}^{60^{\circ}\text{F.}}$ | V% | g%     | $S_{60^{\circ}\text{F.}}^{60^{\circ}\text{F.}}$ | V%  | g%      | $S_{60^{\circ}\text{F.}}^{60^{\circ}\text{F.}}$ |
|----|--------|---|----|--------|---|----|--------|---|-----|---------|---|
| 0  | 0.000  | 1.00000   | 25 | 20.443 | .97084  | 50 | 42.487 | .93426  | 75  | 67.870  | .87728  |
| 1  | 0.795  | .99850  | 26 | 21.285 | .96978  | 51 | 43.428 | .930  | 76  | 68.982  | .865  |
| 2  | 1.593  | .99703  | 27 | 22.127 | .96870  | 52 | 44.374 | .92830  | 77  | 70.102  | .862  |
| 3  | 2.392  | .99559  | 28 | 22.973 | .96760  | 53 | 45.326 | .92630  | 78  | 71.234  | .860  |
| 4  | 3.194  | .99419  | 29 | 23.820 | .96648  | 54 | 46.283 | .92426  | 79  | 72.375  | .858  |
| 5  | 3.998  | .99282  | 30 | 24.670 | .96534  | 55 | 47.245 | .92219  | 80  | 73.526  | .856  |
| 6  | 4.804  | .99150  | 31 | 25.524 | .96418  | 56 | 48.214 | .92010  | 81  | 74.686  | .854  |
| 7  | 5.612  | .99022  | 32 | 26.382 | .96296  | 57 | 49.187 | .91799  | 82  | 75.858  | .852  |
| 8  | 6.422  | .98899  | 33 | 27.242 | .96170  | 58 | 50.167 | .91584  | 83  | 77.039  | .850  |
| 9  | 7.234  | .98779  | 34 | 28.104 | .96041  | 59 | 51.154 | .91365  | 84  | 78.233  | .848  |
| 10 | 8.047  | .98661  | 35 | 28.971 | .95908  | 60 | 52.147 | .91142  | 85  | 79.441  | .846  |
| 11 | 8.862  | .98544  | 36 | 29.842 | .95770  | 61 | 53.146 | .90915  | 86  | 80.662  | .844  |
| 12 | 9.679  | .98430  | 37 | 30.717 | .95628  | 62 | 54.152 | .90684  | 87  | 81.897  | .842  |
| 13 | 10.497 | .98319  | 38 | 31.596 | .95482  | 63 | 55.165 | .90449  | 88  | 83.144  | .840  |
| 14 | 11.317 | .98210  | 39 | 32.478 | .95332  | 64 | 56.184 | .90210  | 89  | 84.408  | .838  |
| 15 | 12.138 | .98104  | 40 | 33.364 | .95178  | 65 | 57.208 | .90000  | 90  | 85.689  | .836  |
| 16 | 12.961 | .97998  | 41 | 34.254 | .95020  | 66 | 58.241 | .89787  | 91  | 86.989  | .834  |
| 17 | 13.786 | .97895  | 42 | 35.150 | .94858  | 67 | 59.279 | .89570  | 92  | 88.310  | .832  |
| 18 | 14.612 | .97794  | 43 | 36.050 | .94693  | 68 | 60.325 | .89349  | 93  | 89.652  | .830  |
| 19 | 15.440 | .97694  | 44 | 36.955 | .94524  | 69 | 61.379 | .89124  | 94  | 91.025  | .828  |
| 20 | 16.269 | .97596  | 45 | 37.865 | .94351  | 70 | 62.441 | .88895  | 95  | 92.423  | .826  |
| 21 | 17.100 | .97496  | 46 | 38.778 | .94174  | 71 | 63.511 | .88662  | 96  | 93.851  | .824  |
| 22 | 17.933 | .97395  | 47 | 39.697 | .93993  | 72 | 64.588 | .88426  | 97  | 95.315  | .822  |
| 23 | 18.768 | .97293  | 48 | 40.622 | .93808  | 73 | 65.674 | .88187  | 98  | 96.820  | .820  |
| 24 | 19.604 | .97189  | 49 | 41.551 | .93619  | 74 | 66.768 | .87944  | 99  | 98.381  | .818  |
| 25 | 20.443 | .97084  | 50 | 42.487 | .93426  | 75 | 67.870 | .87728  | 100 | 100.000 | .816  |

SPECIFIC GRAVITY AND COMPOSITION OF  
MIXTURES OF ETHYL ALCOHOL AND WATER  
AT 60° F.

V% = volume of alcohol in 100 cc. of mixture at 60° F.

g% = weight of alcohol in 100 gms. of mixture.

| g% | V%     | $S_{\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}}$ | g% | V%     | $S_{\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}}$ | g% | V%     | $S_{\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}}$ | g%  | V%      | $S_{\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}}$ |
|----|--------|---|----|--------|---|----|--------|---|-----|---------|---|
| 0  | 0.000  | 1.00000   | 25 | 30.388 | .96489  | 50 | 57.830 | .91821  | 75  | 81.269  | .86024  |
| 1  | 1.257  | .99812  | 26 | 31.555 | .96351  | 51 | 58.844 | .91600  | 76  | 82.121  | .85783  |
| 2  | 2.510  | .99629  | 27 | 32.719 | .96207  | 52 | 59.852 | .91377  | 77  | 82.967  | .85541  |
| 3  | 3.758  | .99452  | 28 | 33.879 | .96057  | 53 | 60.854 | .91153  | 78  | 83.805  | .85298  |
| 4  | 5.002  | .99282  | 29 | 35.033 | .95903  | 54 | 61.850 | .90927  | 79  | 84.636  | .85052  |
| 5  | 6.243  | .99118  | 30 | 36.181 | .95745  | 55 | 62.837 | .90701  | 80  | 85.459  | .84806  |
| 6  | 7.479  | .98963  | 31 | 37.323 | .95582  | 56 | 63.820 | .90475  | 81  | 86.275  | .84558  |
| 7  | 8.712  | .98813  | 32 | 38.459 | .95414  | 57 | 64.798 | .90249  | 82  | 87.083  | .84310  |
| 8  | 9.943  | .98667  | 33 | 39.590 | .95242  | 58 | 65.768 | .90022  | 83  | 87.885  | .84061  |
| 9  | 11.169 | .98524  | 34 | 40.716 | .95065  | 59 | 66.732 | .89793  | 84  | 88.678  | .83810  |
| 10 | 12.393 | .98386  | 35 | 41.832 | .94886  | 60 | 67.690 | .89563  | 85  | 89.464  | .83557  |
| 11 | 13.613 | .98253  | 36 | 42.944 | .94703  | 61 | 68.641 | .89333  | 86  | 90.240  | .83302  |
| 12 | 14.832 | .98122  | 37 | 44.050 | .94516  | 62 | 69.586 | .89101  | 87  | 91.008  | .83046  |
| 13 | 16.047 | .97993  | 38 | 45.149 | .94325  | 63 | 70.523 | .88869  | 88  | 91.766  | .82788  |
| 14 | 17.259 | .97869  | 39 | 46.242 | .94130  | 64 | 71.455 | .88636  | 89  | 92.517  | .82523  |
| 15 | 18.469 | .97747  | 40 | 47.328 | .93933  | 65 | 72.380 | .88402  | 90  | 93.254  | .82260  |
| 16 | 19.676 | .97627  | 41 | 48.407 | .93732  | 66 | 73.299 | .88167  | 91  | 93.982  | .81991  |
| 17 | 20.880 | .97508  | 42 | 49.480 | .93527  | 67 | 74.211 | .87932  | 92  | 94.700  | .81719  |
| 18 | 22.081 | .97388  | 43 | 50.545 | .93319  | 68 | 75.117 | .87698  | 93  | 95.407  | .81443  |
| 19 | 23.278 | .97264  | 44 | 51.605 | .93110  | 69 | 76.016 | .87461  | 94  | 96.103  | .81164  |
| 20 | 24.472 | .97140  | 45 | 52.658 | .92899  | 70 | 76.909 | .87224  | 95  | 96.787  | .80881  |
| 21 | 25.662 | .97014  | 46 | 53.705 | .92687  | 71 | 77.794 | .86986  | 96  | 97.459  | .80595  |
| 22 | 26.849 | .96887  | 47 | 54.746 | .92472  | 72 | 78.672 | .86746  | 97  | 98.117  | .80303  |
| 23 | 28.032 | .96756  | 48 | 55.780 | .92256  | 73 | 79.544 | .86506  | 98  | 98.759  | .80005  |
| 24 | 29.210 | .96624  | 49 | 56.808 | .92039  | 74 | 80.410 | .86266  | 99  | 99.386  | .79700  |
| 25 | 30.388 | .96489  | 50 | 57.830 | .91821  | 75 | 81.269 | .86024  | 100 | 100.000 | .79389  |

# COMPOSITION OF ETHYL ALCOHOL AND WATER MIXTURES AT 60°F.

$V\%$  = percentage of alcohol by volume.

$G_M$  = mass in gms. of 1 litre of mixture.

$G_A$  = mass in gms. of alcohol contained in 1 litre of mixture.

$V_A$  = volume in millilitres of alcohol required to make 1 litre of mixture.

$V_W$  = volume in millilitres of water required to make 1 litre of mixture.

$v$  = contraction in millilitres due to admixture.

| $V\%$ | $G_M$  | $G_A$  | $V_A$ | $V_W$   | $v$   |
|-------|--------|--------|-------|---------|-------|
| 0     | 999.04 | 0.00   | 0     | 1000.00 | 0.00  |
| 1     | 997.54 | 7.93   | 10    | 990.56  | 0.56  |
| 2     | 996.07 | 15.86  | 20    | 981.15  | 1.15  |
| 3     | 994.64 | 23.79  | 30    | 971.78  | 1.78  |
| 4     | 993.24 | 31.73  | 40    | 962.43  | 2.43  |
| 5     | 991.87 | 39.66  | 50    | 953.12  | 3.12  |
| 6     | 990.85 | 47.59  | 60    | 943.87  | 3.87  |
| 7     | 989.27 | 55.52  | 70    | 934.65  | 4.65  |
| 8     | 988.04 | 63.45  | 80    | 925.48  | 5.48  |
| 9     | 986.84 | 71.38  | 90    | 916.34  | 6.34  |
| 10    | 985.66 | 79.31  | 100   | 907.22  | 7.22  |
| 11    | 984.49 | 87.24  | 110   | 898.11  | 8.11  |
| 12    | 983.36 | 95.18  | 120   | 889.03  | 9.03  |
| 13    | 982.25 | 103.11 | 130   | 879.98  | 9.98  |
| 14    | 981.16 | 111.04 | 140   | 870.96  | 10.96 |
| 15    | 980.10 | 118.97 | 150   | 861.96  | 11.96 |
| 16    | 979.04 | 126.90 | 160   | 852.96  | 12.96 |
| 17    | 978.01 | 134.83 | 170   | 843.99  | 13.99 |
| 18    | 977.00 | 142.76 | 180   | 835.04  | 15.04 |
| 19    | 976.00 | 150.69 | 190   | 826.01  | 16.01 |
| 20    | 975.02 | 158.63 | 200   | 817.17  | 17.17 |
| 21    | 974.03 | 166.56 | 210   | 808.25  | 18.25 |
| 22    | 973.02 | 174.49 | 220   | 799.30  | 19.30 |
| 23    | 972.00 | 182.42 | 230   | 790.34  | 20.34 |
| 24    | 970.95 | 190.35 | 240   | 781.35  | 21.35 |
| 25    | 969.91 | 198.28 | 250   | 772.37  | 22.37 |

| $V\%$ | $G_M$  | $G_A$  | $V_A$ | $V_W$  | $v$   |
|-------|--------|--------|-------|--------|-------|
| 26    | 968.85 | 206.21 | 260   | 763.37 | 23.37 |
| 27    | 967.77 | 214.14 | 270   | 754.35 | 24.35 |
| 28    | 966.67 | 222.08 | 280   | 745.30 | 25.30 |
| 29    | 965.55 | 230.01 | 290   | 736.25 | 26.25 |
| 30    | 964.41 | 237.94 | 300   | 727.17 | 27.17 |
| 31    | 963.26 | 245.87 | 310   | 718.08 | 28.08 |
| 32    | 962.04 | 253.80 | 320   | 708.92 | 28.92 |
| 33    | 960.78 | 261.73 | 330   | 699.72 | 29.72 |
| 34    | 959.49 | 269.66 | 340   | 690.49 | 30.49 |
| 35    | 958.16 | 277.60 | 350   | 681.21 | 31.21 |
| 36    | 956.78 | 285.53 | 360   | 671.89 | 31.89 |
| 37    | 955.36 | 293.46 | 370   | 662.54 | 32.54 |
| 38    | 953.90 | 301.39 | 380   | 653.14 | 33.14 |
| 39    | 952.41 | 309.32 | 390   | 643.71 | 33.71 |
| 40    | 950.87 | 317.25 | 400   | 634.23 | 34.23 |
| 41    | 949.29 | 325.18 | 410   | 624.71 | 34.71 |
| 42    | 947.67 | 333.11 | 420   | 615.15 | 35.15 |
| 43    | 946.02 | 341.05 | 430   | 605.55 | 35.55 |
| 44    | 944.33 | 348.98 | 440   | 595.92 | 35.92 |
| 45    | 942.61 | 356.91 | 450   | 586.26 | 36.26 |
| 46    | 940.84 | 364.84 | 460   | 576.55 | 36.55 |
| 47    | 939.03 | 372.77 | 470   | 566.80 | 36.80 |
| 48    | 937.18 | 380.70 | 480   | 557.01 | 37.01 |
| 49    | 935.29 | 388.63 | 490   | 547.18 | 37.18 |
| 50    | 933.36 | 396.56 | 500   | 537.32 | 37.32 |
| 51    | 931.41 | 404.50 | 510   | 527.42 | 37.42 |
| 52    | 929.42 | 412.43 | 520   | 517.49 | 37.49 |
| 53    | 927.42 | 420.36 | 530   | 507.55 | 37.55 |
| 54    | 925.37 | 428.29 | 540   | 497.56 | 37.56 |
| 55    | 923.30 | 436.22 | 550   | 487.55 | 37.55 |
| 56    | 921.21 | 444.15 | 560   | 477.52 | 37.52 |
| 57    | 919.11 | 452.08 | 570   | 467.48 | 37.48 |
| 58    | 916.96 | 460.01 | 580   | 457.34 | 37.34 |
| 59    | 914.77 | 467.95 | 590   | 447.25 | 37.25 |
| 60    | 912.56 | 475.88 | 600   | 437.10 | 37.10 |
| 61    | 910.33 | 483.81 | 610   | 426.93 | 36.93 |
| 62    | 908.06 | 491.74 | 620   | 416.72 | 36.72 |
| 63    | 905.77 | 499.67 | 630   | 406.49 | 36.49 |

| $V\%$ | $G_M$  | $G_A$  | $V_A$ | $V_W$  | $v$   |
|-------|--------|--------|-------|--------|-------|
| 64    | 903.47 | 507.60 | 640   | 396.25 | 36.25 |
| 65    | 901.15 | 515.53 | 650   | 385.99 | 35.99 |
| 66    | 898.81 | 523.46 | 660   | 375.71 | 35.71 |
| 67    | 896.43 | 531.40 | 670   | 365.38 | 35.38 |
| 68    | 894.03 | 539.33 | 680   | 355.04 | 35.04 |
| 69    | 891.59 | 547.26 | 690   | 344.66 | 34.66 |
| 70    | 889.14 | 555.19 | 700   | 334.27 | 34.27 |
| 71    | 886.66 | 563.12 | 710   | 323.85 | 33.85 |
| 72    | 884.14 | 571.05 | 720   | 313.39 | 33.39 |
| 73    | 881.59 | 578.98 | 730   | 302.90 | 32.90 |
| 74    | 879.03 | 586.92 | 740   | 292.39 | 32.39 |
| 75    | 876.44 | 594.85 | 750   | 281.86 | 31.86 |
| 76    | 873.81 | 602.78 | 760   | 271.29 | 31.29 |
| 77    | 871.15 | 610.71 | 770   | 260.69 | 30.69 |
| 78    | 868.46 | 618.64 | 780   | 250.06 | 30.06 |
| 79    | 865.73 | 626.57 | 790   | 239.38 | 29.38 |
| 80    | 862.97 | 634.50 | 800   | 228.69 | 28.68 |
| 81    | 860.17 | 642.43 | 810   | 217.95 | 27.95 |
| 82    | 857.35 | 650.37 | 820   | 207.18 | 27.18 |
| 83    | 854.49 | 658.30 | 830   | 196.38 | 26.36 |
| 84    | 851.58 | 666.23 | 840   | 185.53 | 25.53 |
| 85    | 848.63 | 674.16 | 850   | 174.64 | 24.64 |
| 86    | 845.61 | 682.09 | 860   | 163.68 | 23.68 |
| 87    | 842.55 | 690.02 | 870   | 152.68 | 22.68 |
| 88    | 839.44 | 697.95 | 880   | 141.63 | 21.63 |
| 89    | 836.27 | 705.88 | 890   | 130.52 | 20.52 |
| 90    | 833.02 | 713.82 | 900   | 119.31 | 19.31 |
| 91    | 829.69 | 721.75 | 910   | 108.04 | 18.04 |
| 92    | 826.26 | 729.68 | 920   | 96.63  | 16.63 |
| 93    | 822.72 | 737.61 | 930   | 85.19  | 15.19 |
| 94    | 819.05 | 745.54 | 940   | 73.58  | 13.58 |
| 95    | 815.25 | 753.47 | 950   | 61.84  | 11.84 |
| 96    | 811.28 | 761.40 | 960   | 49.93  | 9.93  |
| 97    | 807.15 | 769.33 | 970   | 37.86  | 7.86  |
| 98    | 802.79 | 777.27 | 980   | 25.54  | 5.54  |
| 99    | 798.12 | 785.20 | 990   | 12.93  | 2.93  |
| 100   | 793.13 | 793.13 | 1000  | 0.00   | 0.00  |

# CHANGE IN DENSITY OF MIXTURES OF ETHYL ALCOHOL AND WATER WITH TEMPERATURE.

$g\%$  = gms. of alcohol in 100 gms. of mixture.

$d_C$  = change in density per  $^{\circ}\text{C}$ . difference in temp. from  $15^{\circ}\text{C}$ .

$d_F$  = change in density per  $^{\circ}\text{F}$ . difference in temp. from  $60^{\circ}\text{F}$ .

| $g\%$ | $d_C$ | $d_F$ | $g\%$ | $d_C$ | $d_F$ | $g\%$ | $d_C$ | $d_F$ | $g\%$ | $d_C$ | $d_F$ |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0     | 15    | 8     | 25    | 50    | 28    | 50    | 78    | 43    | 75    | 84    | 47    |
| 1     | 15    | 8     | 26    | 52    | 29    | 51    | 78    | 44    | 76    | 85    | 47    |
| 2     | 15    | 8     | 27    | 54    | 30    | 52    | 79    | 44    | 77    | 85    | 47    |
| 3     | 15    | 8     | 28    | 56    | 31    | 53    | 79    | 44    | 78    | 85    | 47    |
| 4     | 16    | 9     | 29    | 58    | 32    | 54    | 79    | 44    | 79    | 85    | 47    |
| 5     | 16    | 9     | 30    | 60    | 33    | 55    | 80    | 44    | 80    | 85    | 47    |
| 6     | 17    | 9     | 31    | 61    | 34    | 56    | 80    | 44    | 81    | 85    | 47    |
| 7     | 17    | 10    | 32    | 63    | 35    | 57    | 80    | 45    | 82    | 85    | 47    |
| 8     | 18    | 10    | 33    | 64    | 36    | 58    | 81    | 45    | 83    | 85    | 47    |
| 9     | 19    | 11    | 34    | 66    | 36    | 59    | 81    | 45    | 84    | 86    | 48    |
| 10    | 21    | 11    | 35    | 67    | 37    | 60    | 81    | 45    | 85    | 86    | 48    |
| 11    | 22    | 12    | 36    | 68    | 38    | 61    | 82    | 45    | 86    | 86    | 48    |
| 12    | 24    | 13    | 37    | 69    | 38    | 62    | 82    | 45    | 87    | 86    | 48    |
| 13    | 25    | 14    | 38    | 70    | 39    | 63    | 82    | 46    | 88    | 86    | 48    |
| 14    | 27    | 15    | 39    | 71    | 40    | 64    | 82    | 46    | 89    | 86    | 48    |
| 15    | 29    | 16    | 40    | 72    | 40    | 65    | 83    | 46    | 90    | 86    | 48    |
| 16    | 31    | 17    | 41    | 73    | 40    | 66    | 83    | 46    | 91    | 86    | 48    |
| 17    | 32    | 18    | 42    | 74    | 41    | 67    | 83    | 46    | 92    | 86    | 48    |
| 18    | 34    | 19    | 43    | 74    | 41    | 68    | 83    | 46    | 93    | 86    | 48    |
| 19    | 37    | 20    | 44    | 75    | 42    | 69    | 84    | 46    | 94    | 86    | 48    |
| 20    | 39    | 22    | 45    | 75    | 42    | 70    | 84    | 46    | 95    | 85    | 47    |
| 21    | 41    | 23    | 46    | 76    | 42    | 71    | 84    | 47    | 96    | 85    | 47    |
| 22    | 43    | 24    | 47    | 77    | 43    | 72    | 84    | 47    | 97    | 85    | 47    |
| 23    | 45    | 25    | 48    | 77    | 43    | 73    | 84    | 47    | 98    | 85    | 47    |
| 24    | 48    | 26    | 49    | 78    | 43    | 74    | 84    | 47    | 99    | 85    | 47    |
| 25    | 50    | 28    | 50    | 78    | 43    | 75    | 84    | 47    | 100   | 85    | 47    |

NOTE.—The values given in the above table for  $d_C$  and  $d_F$  must be divided by  $10^5$ .



## DILUTION OF ETHYL ALCOHOL AND WATER MIXTURES AT 60°F.

The figures given in the table represent the volumes of water which must be added to 100 volumes of mixtures of the percentage strengths shown at the side of the table to give mixtures of the percentage strengths shown at the head of the table.

*Percentage by volume after dilution.*

|     | 95.  | 90.   | 85.   | 80.   | 75.   | 70.   | 65.   | 60.   | 55.   | 50.    | 45.    | 40.    | 35.    | 30.    | 25.    | 20.    | 15.    | 10.    | 5.      |
|-----|------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|
| 100 | 6.51 | 13.26 | 20.55 | 28.59 | 37.58 | 47.75 | 59.38 | 72.85 | 88.63 | 107.46 | 130.28 | 158.56 | 194.63 | 242.39 | 308.95 | 408.59 | 574.64 | 907.22 | 1906.24 |
| 95  | —    | 6.41  | 13.34 | 20.97 | 29.52 | 39.18 | 50.23 | 63.02 | 78.02 | 95.91  | 117.58 | 144.45 | 178.72 | 224.09 | 287.32 | 381.97 | 539.72 | 855.68 | 1804.74 |
| 90  | —    | —     | 6.56  | 13.80 | 21.89 | 31.05 | 41.51 | 53.63 | 67.84 | 84.79  | 105.32 | 130.77 | 163.27 | 206.22 | 266.12 | 355.80 | 505.25 | 804.57 | 1703.69 |
| 85  | —    | —     | —     | 6.83  | 14.48 | 23.12 | 33.01 | 44.46 | 57.87 | 73.88  | 93.27  | 117.31 | 147.97 | 188.57 | 245.14 | 329.83 | 470.98 | 753.67 | 1602.84 |
| 80  | —    | —     | —     | —     | 7.20  | 15.33 | 24.64 | 35.41 | 48.04 | 63.10  | 81.36  | 103.98 | 132.84 | 171.04 | 224.29 | 304.00 | 436.84 | 702.91 | 1502.12 |
| 75  | —    | —     | —     | —     | —     | 7.63  | 16.35 | 26.45 | 38.29 | 52.41  | 69.52  | 90.73  | 117.79 | 153.61 | 203.53 | 278.25 | 402.79 | 652.23 | 1401.49 |
| 70  | —    | —     | —     | —     | —     | —     | 8.14  | 17.57 | 28.62 | 41.80  | 57.77  | 77.56  | 102.82 | 136.25 | 182.84 | 252.58 | 368.82 | 601.63 | 1300.94 |
| 65  | —    | —     | —     | —     | —     | —     | —     | 8.75  | 19.01 | 31.25  | 46.08  | 64.46  | 87.91  | 118.96 | 162.22 | 226.98 | 334.92 | 551.09 | 1200.46 |
| 60  | —    | —     | —     | —     | —     | —     | —     | —     | 9.47  | 20.77  | 34.46  | 51.43  | 73.07  | 101.72 | 141.68 | 241.44 | 301.07 | 500.62 | 1100.03 |
| 55  | —    | —     | —     | —     | —     | —     | —     | —     | —     | 10.35  | 22.90  | 38.45  | 58.29  | 84.56  | 121.17 | 175.97 | 267.30 | 450.22 | 999.68  |
| 50  | —    | —     | —     | —     | —     | —     | —     | —     | —     | —      | 11.41  | 25.55  | 43.58  | 67.46  | 100.74 | 150.56 | 233.59 | 399.88 | 899.39  |
| 45  | —    | —     | —     | —     | —     | —     | —     | —     | —     | —      | —      | 12.73  | 28.96  | 50.45  | 80.40  | 125.24 | 199.96 | 349.62 | 799.18  |
| 40  | —    | —     | —     | —     | —     | —     | —     | —     | —     | —      | —      | —      | 14.43  | 33.53  | 59.16  | 100.01 | 166.43 | 299.47 | 699.07  |
| 35  | —    | —     | —     | —     | —     | —     | —     | —     | —     | —      | —      | —      | —      | 16.72  | 40.01  | 74.88  | 133.00 | 249.41 | 599.06  |
| 30  | —    | —     | —     | —     | —     | —     | —     | —     | —     | —      | —      | —      | —      | —      | 19.97  | 50.86  | 99.68  | 199.45 | 499.16  |
| 25  | —    | —     | —     | —     | —     | —     | —     | —     | —     | —      | —      | —      | —      | —      | —      | 24.91  | 66.42  | 149.57 | 399.32  |
| 20  | —    | —     | —     | —     | —     | —     | —     | —     | —     | —      | —      | —      | —      | —      | —      | —      | 33.21  | 99.73  | 299.53  |
| 15  | —    | —     | —     | —     | —     | —     | —     | —     | —     | —      | —      | —      | —      | —      | —      | —      | —      | 49.89  | 199.74  |
| 10  | —    | —     | —     | —     | —     | —     | —     | —     | —     | —      | —      | —      | —      | —      | —      | —      | —      | —      | 99.90   |

Original Percentage by volume.

## SP. GR. OF ETHYL ALCOHOL—ETHER MIXTURES.

(F. BAKER, *J. Chem. Soc.*, 1912, 101, p. 1411.) $g$  = weight of ether in 100 gms. of mixture.

| $g$ | $S_{25^{\circ}\text{C.}}^{4^{\circ}\text{C.}}$ | $g$ | $S_{25^{\circ}\text{C.}}^{4^{\circ}\text{C.}}$ | $g$ | $S_{25^{\circ}\text{C.}}^{4^{\circ}\text{C.}}$ |
|-----|--|-----|--|-----|--|
| 0   | 0.788  | 40  | 0.760  | 70  | 0.736  |
| 10  | 0.781  | 50  | 0.752  | 80  | 0.728  |
| 20  | 0.774  | 50  | 0.752  | 90  | 0.718  |
| 30  | 0.767  | 60  | 0.744  | 100 | 0.700  |

## Density of Mixtures of Methyl Alcohol and Water.

 $g\%$  = wt. of methyl alcohol in 100 gms. of mixture. $V\%$  = vol. of methyl alcohol in 100 vols. of mixture at  $15^{\circ}\text{C.}$ Based on calculations made by the Bureau of Standards, Washington, from the results of Doroshevskii and Rozhdestvenskii (*J. Russ. Phys. Chem. Soc.* 41, pp. 977—996, 1909).

| $g\%$ | $V\%$  | $S_{15^{\circ}\text{C.}}^{4^{\circ}\text{C.}}$ | $g\%$ | $V\%$  | $S_{15^{\circ}\text{C.}}^{4^{\circ}\text{C.}}$ | $g\%$ | $V\%$  | $S_{15^{\circ}\text{C.}}^{4^{\circ}\text{C.}}$ | $g\%$ | $V\%$   | $S_{15^{\circ}\text{C.}}^{4^{\circ}\text{C.}}$ |
|-------|--------|--|-------|--------|--|-------|--------|--|-------|---------|--|
| 0     | 0.000  | .99913   | 25    | 30.193 | .96108   | 50    | 57.712 | .91852   | 75    | 81.336  | .86300   |
| 1     | 1.253  | .727   | 26    | 31.354 | .95963   | 51    | 58.739 | .91653   | 76    | 82.182  | .86105   |
| 2     | 2.502  | .543   | 27    | 32.510 | .917   | 52    | 59.759 | .91451   | 77    | 83.022  | .85901   |
| 3     | 3.746  | .370   | 28    | 33.662 | .91668   | 53    | 60.773 | .91248   | 78    | 83.855  | .85751   |
| 4     | 4.986  | .198   | 29    | 34.809 | .91518   | 54    | 61.781 | .91044   | 79    | 84.680  | .85600   |
| 5     | 6.222  | .029   | 30    | 35.952 | .91366   | 55    | 62.783 | .90839   | 80    | 85.499  | .85448   |
| 6     | 7.454  | .98864   | 31    | 37.091 | .91213   | 56    | 63.778 | .90631   | 81    | 86.310  | .85294   |
| 7     | 8.682  | .701   | 32    | 38.224 | .91056   | 57    | 64.767 | .90421   | 82    | 87.110  | .85136   |
| 8     | 9.907  | .547   | 33    | 39.352 | .90896   | 58    | 65.750 | .90210   | 83    | 87.899  | .84974   |
| 9     | 11.128 | .394   | 34    | 40.476 | .90734   | 59    | 66.725 | .90096   | 84    | 88.677  | .84809   |
| 10    | 12.345 | .241   | 35    | 41.594 | .90570   | 60    | 67.693 | .89978   | 85    | 89.448  | .84642   |
| 11    | 13.559 | .093   | 36    | 42.708 | .90404   | 61    | 68.654 | .89856   | 86    | 90.212  | .84475   |
| 12    | 14.770 | .97945   | 37    | 43.816 | .90237   | 62    | 69.607 | .89734   | 87    | 90.968  | .84307   |
| 13    | 15.977 | .802   | 38    | 44.919 | .90067   | 63    | 70.552 | .89611   | 88    | 91.716  | .84137   |
| 14    | 17.181 | .660   | 39    | 46.016 | .90894   | 64    | 71.490 | .88890   | 89    | 92.456  | .83967   |
| 15    | 18.382 | .518   | 40    | 47.109 | .90720   | 65    | 72.420 | .88716   | 90    | 93.188  | .83796   |
| 16    | 19.579 | .377   | 41    | 48.195 | .90543   | 66    | 73.344 | .88543   | 91    | 93.912  | .83624   |
| 17    | 20.773 | .237   | 42    | 49.277 | .90365   | 67    | 74.262 | .88369   | 92    | 94.627  | .83451   |
| 18    | 21.963 | .096   | 43    | 50.353 | .90185   | 68    | 75.172 | .88191   | 93    | 95.326  | .83278   |
| 19    | 23.149 | .96955   | 44    | 51.422 | .90001   | 69    | 76.077 | .88007   | 94    | 96.017  | .83105   |
| 20    | 24.332 | .814   | 45    | 52.486 | .90815   | 70    | 76.976 | .87820   | 95    | 96.697  | .82932   |
| 21    | 25.512 | .673   | 46    | 53.544 | .90627   | 71    | 77.864 | .87631   | 96    | 97.370  | .82759   |
| 22    | 26.688 | .533   | 47    | 54.595 | .90436   | 72    | 78.746 | .87440   | 97    | 98.036  | .82586   |
| 23    | 27.860 | .392   | 48    | 55.639 | .90242   | 73    | 79.618 | .87249   | 98    | 98.696  | .82413   |
| 24    | 29.029 | .251   | 49    | 56.678 | .90048   | 74    | 80.480 | .87056   | 99    | 99.351  | .82240   |
| 25    | 30.193 | .108   | 50    | 57.712 | .90852   | 75    | 81.336 | .86860   | 100   | 100.000 | .82067   |

## Specific Gravity of Aluminium Chloride Solutions

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 281.)

$g\%$  = grms. of  $\text{Al}_2\text{Cl}_6$  in 100 grms. of solution.

| $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|-------|---|
| 1     | 1.00721                                     | 12    | 1.08902                                     | 23    | 1.17953                                     | 34    | 1.28080                                     |
| 2     | 1443  | 13    | 9684  | 24    | 8815  | 35    | 9046  |
| 3     | 2164  | 14    | 1.10466                                     | 25    | 9676  | 36    | 1.30066                                     |
| 4     | 2885  | 15    | 1248  | 26    | 1.20584                                     | 37    | 1086  |
| 5     | 3606  | 16    | 2073  | 27    | 1493  | 38    | 2106  |
| 6     | 4353  | 17    | 2897  | 28    | 2406  | 39    | 3126  |
| 7     | 5099  | 18    | 3721  | 29    | 3310  | 40    | 4146  |
| 8     | 5845  | 19    | 4545  | 30    | 4219  | 41    | 5224  |
| 9     | 6591  | 20    | 5370  | 31    | 5184  |       |   |
| 10    | 7337  | 21    | 6231  | 32    | 6149  |       |   |
| 11    | 8120  | 22    | 7092  | 33    | 7115  |       |   |

## Specific Gravity of Aluminium Sulphate Solutions

(Reuss, *Ber. Chem. Ges.*, 1884, **17**, 2888.)

$g\%$  = grms. of  $\text{Al}_2(\text{SO}_4)_3$  in 100 grms. of solution.

| $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|-------|---|
| 1     | 1.0170                                      | 8     | 1.0870                                      | 15    | 1.1574                                      | 22    | 1.2274                                      |
| 2     | 270   | 9     | 968   | 16    | 668   | 23    | 375   |
| 3     | 370   | 10    | 1.1071                                      | 17    | 770   | 24    | 473   |
| 4     | 470   | 11    | 171   | 18    | 876   | 25    | 572   |
| 5     | 569   | 12    | 270   | 19    | 971   |       |   |
| 6     | 670   | 13    | 369   | 20    | 1.2074                                      |       |   |
| 7     | 768   | 14    | 467   | 21    | 168   |       |   |

## Specific Gravity of Ammonia Alum Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 495.)

$g\%$  = grms. of  $(\text{NH}_4)_2\text{SO}_4\text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$ .

| $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ |
|-------|---|-------|---|
| 3     | 1.0141                                      | 9     | 1.0423                                      |
| 6     | 1.0282                                      |       |   |

# Specific Gravity of Ammonia Solutions at 15° C.

(Lunge and Wiernik, *Z. angew. Chem.*, 1889, **2**, 181.)

$g\%$  = grms.  $\text{NH}_3$  in 100 grms. of solution

$G$  = grms.  $\text{NH}_3$  in 1 litre of solution.

$C$  = Fall in Sp. Gr. for 1°C. rise in temperature.

| $S_{15^\circ\text{C.}}$<br>$15^\circ\text{C.}$ | $g\%$ | $G.$  | $C.$    | $S_{15^\circ\text{C.}}$<br>$15^\circ\text{C.}$ | $g\%$ | $G.$  | $C.$    |
|--|-------|-------|---------|--|-------|-------|---------|
| 1.000  | 0.00  | 0.0   | 0.00018 | 0.940  | 15.63 | 146.9 | 0.00039 |
| 0.998  | 0.45  | 4.5   | 0.00018 | 0.938  | 16.22 | 152.1 | 0.00040 |
| 0.996  | 0.91  | 9.1   | 0.00019 | 0.936  | 16.82 | 157.4 | 0.00041 |
| 0.994  | 1.37  | 13.6  | 0.00019 | 0.934  | 17.42 | 162.7 | 0.00041 |
| 0.992  | 1.84  | 18.2  | 0.00020 | 0.932  | 18.03 | 168.1 | 0.00042 |
| 0.990  | 2.31  | 22.9  | 0.00020 | 0.930  | 18.64 | 173.4 | 0.00042 |
| 0.988  | 2.80  | 27.7  | 0.00021 | 0.928  | 19.25 | 178.6 | 0.00043 |
| 0.986  | 3.30  | 32.5  | 0.00021 | 0.926  | 19.87 | 184.2 | 0.00044 |
| 0.984  | 3.80  | 37.4  | 0.00022 | 0.924  | 20.49 | 189.3 | 0.00045 |
| 0.982  | 4.30  | 42.2  | 0.00022 | 0.922  | 21.12 | 194.7 | 0.00046 |
| 0.980  | 4.80  | 47.0  | 0.00023 | 0.920  | 21.75 | 200.1 | 0.00047 |
| 0.978  | 5.30  | 51.8  | 0.00023 | 0.918  | 22.39 | 205.6 | 0.00048 |
| 0.976  | 5.80  | 56.6  | 0.00024 | 0.916  | 23.03 | 210.9 | 0.00049 |
| 0.974  | 6.30  | 61.4  | 0.00024 | 0.914  | 23.68 | 216.3 | 0.00050 |
| 0.972  | 6.80  | 66.1  | 0.00025 | 0.912  | 24.33 | 221.9 | 0.00051 |
| 0.970  | 7.31  | 70.9  | 0.00025 | 0.910  | 24.99 | 227.4 | 0.00052 |
| 0.968  | 7.82  | 75.7  | 0.00026 | 0.908  | 25.65 | 232.9 | 0.00053 |
| 0.966  | 8.33  | 80.5  | 0.00026 | 0.906  | 26.31 | 238.3 | 0.00054 |
| 0.964  | 8.84  | 85.2  | 0.00027 | 0.904  | 26.98 | 243.9 | 0.00055 |
| 0.962  | 9.35  | 89.9  | 0.00028 | 0.902  | 27.65 | 249.4 | 0.00056 |
| 0.960  | 9.91  | 95.1  | 0.00029 | 0.900  | 28.33 | 255.0 | 0.00057 |
| 0.958  | 10.47 | 100.3 | 0.00030 | 0.898  | 29.01 | 260.5 | 0.00058 |
| 0.956  | 11.03 | 105.4 | 0.00031 | 0.896  | 29.69 | 266.0 | 0.00059 |
| 0.954  | 11.60 | 110.7 | 0.00032 | 0.894  | 30.37 | 271.5 | 0.00060 |
| 0.952  | 12.17 | 115.9 | 0.00033 | 0.892  | 31.05 | 277.0 | 0.00060 |
| 0.950  | 12.74 | 121.0 | 0.00034 | 0.890  | 31.75 | 282.6 | 0.00061 |
| 0.948  | 13.31 | 126.2 | 0.00035 | 0.888  | 32.50 | 288.6 | 0.00062 |
| 0.946  | 13.88 | 131.3 | 0.00036 | 0.886  | 33.25 | 294.6 | 0.00063 |
| 0.944  | 14.46 | 136.5 | 0.00037 | 0.884  | 34.10 | 301.4 | 0.00064 |
| 0.942  | 15.04 | 141.7 | 0.00038 | 0.882  | 34.95 | 308.3 | 0.00065 |

## Specific Gravity of Ammonia Chrome Alum Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 497.)

$g\%$  = gms. of  $(\text{NH}_4)_2\text{SO}_4\text{Cr}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$  in 100 gms. of solution.

| $g\%$ | $S_{15^\circ\text{C.}}$<br>$15^\circ\text{C.}$ | $g\%$ | $S_{15^\circ\text{C.}}$<br>$15^\circ\text{C.}$ |
|-------|--|-------|--|
| 4     | 1.0200   | 12    | 1.0610   |
| 8     | 1.0405   |       |  |

## Specific Gravity of Ammonia Iron Alum Solutions

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 496.)

$g\%$  = grms. of  $(\text{NH}_4)_2\text{SO}_4\text{Fe}_2(\text{SO}_4)_3\cdot 24\text{H}_2\text{O}$  in 100 grms. of solution.

| $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ |
|-------|---|-------|---|
| 5     | 1.023   | 25    | 1.122   |
| 10    | .047  | 30    | .148  |
| 15    | .071  | 35    | .175  |
| 20    | .096  | 40    | .203  |

## Specific Gravity of Ammonium Acetate Solutions

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 313.)

$g\%$  = grms. of  $\text{CH}_3\text{COONH}_4$  in 100 grms. of solution.

| $g\%$ | $S_{\frac{16^\circ\text{C.}}{16^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{16^\circ\text{C.}}{16^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{16^\circ\text{C.}}{16^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 3     | 1.008   | 20    | 1.042   | 37    | 1.0725  |
| 4     | 10  | 21    | 44  | 38    | 740   |
| 5     | 12  | 22    | 46  | 39    | 755   |
| 6     | 14  | 23    | 48  | 40    | 770   |
| 7     | 16  | 24    | 50  | 41    | 785   |
| 8     | 18  | 25    | 52  | 42    | 800   |
| 9     | 20  | 26    | 54  | 43    | 815   |
| 10    | 22  | 27    | 56  | 44    | 830   |
| 11    | 24  | 28    | 58  | 45    | 845   |
| 12    | 26  | 29    | 60  | 46    | 860   |
| 13    | 28  | 30    | 62  | 47    | 875   |
| 14    | 30  | 31    | 636   | 48    | 890   |
| 15    | 32  | 32    | 651   | 49    | 905   |
| 16    | 34  | 33    | 666   | 50    | 920   |
| 17    | 36  | 34    | 681   | 51    | 935   |
| 18    | 38  | 35    | 695   | 52    | 950   |
| 19    | 40  | 36    | 710   |       |   |

## Specific Gravity of Ammonium Carbonate Solutions.

(J. H. Smith, *J.S.C.I.*, 1883, 2, 80.)

$g\%$  = gms. of dry commercial ammonium carbonate of composition  $\text{NH}_3$  31.3%,  $\text{CO}_2$  56.6%,  $\text{H}_2\text{O}$  12.1% in 100 gms. of solution.

C = Fall in Sp. Gr. for  $1^\circ\text{C}$ . rise in temperature.

| $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | C.     | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | C.     |
|-------|---|--------|-------|---|--------|
| 1.66  | 1.005                                       | 0.0002 | 23.78 | 1.080                                       | 0.0006 |
| 3.18  | 10  | 2      | 25.31 | 85  | 6      |
| 4.60  | 15  | 3      | 26.82 | 90  | 7      |
| 6.04  | 20  | 3      | 28.33 | 95  | 7      |
| 7.49  | 25  | 3      | 29.93 | 1.100                                       | 7      |
| 8.93  | 30  | 4      | 31.77 | 05  | 7      |
| 10.35 | 35  | 4      | 33.45 | 10  | 7      |
| 11.86 | 40  | 4      | 35.08 | 15  | 7      |
| 13.36 | 45  | 5      | 36.88 | 20  | 7      |
| 14.83 | 50  | 5      | 38.71 | 25  | 7      |
| 16.16 | 55  | 5      | 40.34 | 30  | 7      |
| 17.70 | 60  | 5      | 42.20 | 35  | 7      |
| 19.18 | 65  | 5      | 44.29 | 40  | 7      |
| 20.70 | 70  | 5      | 44.90 | 41  | 7      |
| 22.25 | 75  | 6      |       |   |        |

## Specific Gravity of Ammonium Chloride Solutions

(Gerlach, *Z. anal. Chem.*, 1869, 8, 281.)

$g\%$  = gms. of  $\text{NH}_4\text{Cl}$  in 100 gms. of solution.

| $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.00316                                     | 10    | 1.03081                                     | 19    | 1.05648                                     |
| 2     | 0632  | 11    | 3370  | 20    | 5929  |
| 3     | 0948  | 12    | 3658  | 21    | 6204  |
| 4     | 1264  | 13    | 3947  | 22    | 6479  |
| 5     | 1580  | 14    | 4325  | 23    | 6754  |
| 6     | 1880  | 15    | 4524  | 24    | 7029  |
| 7     | 2180  | 16    | 4805  | 25    | 7304  |
| 8     | 2481  | 17    | 5086  | 26    | 7575  |
| 9     | 2781  | 18    | 5367  |       |   |

# Specific Gravity of Ammonium Nitrate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 310.)

$g\%$  = gms. of  $\text{NH}_4\text{NO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|-------|---|
| 1     | 1.0042  | 17    | 1.0729  | 33    | 1.1454  | 49    | 1.2249  |
| 2     | 085   | 18    | 773   | 34    | 502   | 50    | 300   |
| 3     | 127   | 19    | 816   | 35    | 550   | 51    | 353   |
| 4     | 170   | 20    | 860   | 36    | 598   | 52    | 407   |
| 5     | 212   | 21    | 905   | 37    | 646   | 53    | 460   |
| 6     | 255   | 22    | 950   | 38    | 694   | 54    | 514   |
| 7     | 297   | 23    | 995   | 39    | 742   | 55    | 567   |
| 8     | 340   | 24    | 1.1040  | 40    | 790   | 56    | 621   |
| 9     | 382   | 25    | 085   | 41    | 841   | 57    | 674   |
| 10    | 425   | 26    | 130   | 42    | 892   | 58    | 728   |
| 11    | 468   | 27    | 175   | 43    | 942   | 59    | 781   |
| 12    | 512   | 28    | 220   | 44    | 994   | 60    | 835   |
| 13    | 555   | 29    | 265   | 45    | 1.2045  | 61    | 888   |
| 14    | 599   | 30    | 310   | 46    | 096   | 62    | 942   |
| 15    | 642   | 31    | 358   | 47    | 147   | 63    | 1.3005  |
| 16    | 686   | 32    | 406   | 48    | 198   | 64    | 059   |

# Sp. Gr. of Ammonium Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 287.)

$g\%$  = gms. of  $(\text{NH}_4)_2\text{SO}_4$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.0057  | 18    | 1.1035  | 35    | 1.2004  |
| 2     | 115   | 19    | 092   | 36    | 060   |
| 3     | 172   | 20    | 149   | 37    | 116   |
| 4     | 230   | 21    | 207   | 38    | 172   |
| 5     | 287   | 22    | 265   | 39    | 228   |
| 6     | 345   | 23    | 323   | 40    | 284   |
| 7     | 403   | 24    | 381   | 41    | 343   |
| 8     | 460   | 25    | 439   | 42    | 402   |
| 9     | 518   | 26    | 496   | 43    | 462   |
| 10    | 575   | 27    | 554   | 44    | 522   |
| 11    | 632   | 28    | 612   | 45    | 583   |
| 12    | 690   | 29    | 670   | 46    | 644   |
| 13    | 747   | 30    | 724   | 47    | 705   |
| 14    | 805   | 31    | 780   | 48    | 766   |
| 15    | 862   | 32    | 836   | 49    | 828   |
| 16    | 920   | 33    | 892   | 50    | 890   |
| 17    | 977   | 34    | 948   |       |   |

# Specific Gravity of Arsenic Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, 27, 316.)

$g\%$  = gms. of  $H_3AsO_4$  in 100 gms. of solution.

| $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ | $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ | $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ |
|-------|---------------------------------|-------|---------------------------------|-------|---------------------------------|
| 1     | 1.006                           | 32    | 1.248                           | 62    | 1.626                           |
| 2     | 13                              | 33    | 57                              | 63    | 43                              |
| 3     | 19                              | 34    | 67                              | 64    | 59                              |
| 4     | 26                              | 35    | 77                              | 65    | 75                              |
| 5     | 32                              | 36    | 88                              | 66    | 93                              |
| 6     | 39                              | 37    | 99                              | 67    | 1.712                           |
| 7     | 46                              | 38    | 1.309                           | 68    | 30                              |
| 8     | 52                              | 39    | 20                              | 69    | 49                              |
| 9     | 59                              | 40    | 31                              | 70    | 67                              |
| 10    | 66                              | 41    | 42                              | 71    | 88                              |
| 11    | 73                              | 42    | 53                              | 72    | 1.809                           |
| 12    | 81                              | 43    | 66                              | 73    | 30                              |
| 13    | 88                              | 44    | 76                              | 74    | 51                              |
| 14    | 96                              | 45    | 87                              | 75    | 72                              |
| 15    | 1.103                           | 46    | 1.400                           | 76    | 97                              |
| 16    | 11                              | 47    | 12                              | 77    | 1.921                           |
| 17    | 19                              | 48    | 25                              | 78    | 46                              |
| 18    | 26                              | 49    | 37                              | 79    | 70                              |
| 19    | 34                              | 50    | 50                              | 80    | 95                              |
| 20    | 42                              | 51    | 64                              | 81    | 2.020                           |
| 21    | 50                              | 52    | 78                              | 82    | 45                              |
| 22    | 58                              | 53    | 91                              | 83    | 70                              |
| 23    | 67                              | 54    | 1.505                           | 84    | 95                              |
| 24    | 75                              | 55    | 19                              | 85    | 2.120                           |
| 25    | 83                              | 56    | 34                              | 86    | 49                              |
| 26    | 92                              | 57    | 49                              | 87    | 78                              |
| 27    | 1.201                           | 58    | 64                              | 88    | 2.207                           |
| 28    | 10                              | 59    | 79                              | 89    | 36                              |
| 29    | 19                              | 60    | 94                              | 90    | 65                              |
| 30    | 28                              | 61    | 1.610                           | 91    | 95                              |
| 31    | 38                              |       |                                 |       |                                 |

# Specific Gravity of Barium Bromide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 285.)

$g\%$  = gms. of  $BaBr_2$  in 100 gms. of solution.

| $g\%$ | $S_{19^\circ 5^\circ C.}^{19^\circ 5^\circ C.}$ | $g\%$ | $S_{19^\circ 5^\circ C.}^{19^\circ 5^\circ C.}$ | $g\%$ | $S_{19^\circ 5^\circ C.}^{19^\circ 5^\circ C.}$ |
|-------|---|-------|---|-------|---|
| 5     | 1.045   | 25    | 1.262   | 45    | 1.580   |
| 10    | .092  | 30    | .329  | 50    | .685  |
| 15    | .144  | 35    | .405  | 55    | .800  |
| 20    | .201  | 40    | .485  |       |   |



## Specific Gravity of Barium Acetate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 313.)

$g\%$  = gms. of  $\text{CH}_3\text{COO} > \text{Ba}$  in 100 gms. of solution.

| $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ | $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ | $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.0087  | 15    | 1.1120  | 29    | 1.2312  |
| 2     | 174   | 16    | 201   | 30    | 402   |
| 3     | 261   | 17    | 282   | 31    | 512   |
| 4     | 348   | 18    | 363   | 32    | 622   |
| 5     | 436   | 19    | 444   | 33    | 732   |
| 6     | 500   | 20    | 522   | 34    | 842   |
| 7     | 564   | 21    | 608   | 35    | 954   |
| 8     | 628   | 22    | 694   | 36    | 1.3075  |
| 9     | 692   | 23    | 780   | 37    | 196   |
| 10    | 758   | 24    | 866   | 38    | 317   |
| 11    | 830   | 25    | 952   | 39    | 438   |
| 12    | 902   | 26    | 1.2042  | 40    | 558   |
| 13    | 974   | 27    | 132   |       |   |
| 14    | 1.1046  | 28    | 222   |       |   |

## Specific Gravity of Barium Chloride Solutions

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 283.)

$g\%$  = gms. of  $\text{BaCl}_2$  in 100 gms. of solution.

| $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.00917                                     | 10    | 1.09508                                     | 19    | 1.19458                                     |
| 2     | 1834  | 11    | 1.10576                                     | 20    | 1.20611                                     |
| 3     | 2750  | 12    | 1643  | 21    | 1892  |
| 4     | 3667  | 13    | 2711  | 22    | 3173  |
| 5     | 4584  | 14    | 3778  | 23    | 4455  |
| 6     | 5569  | 15    | 4846  | 24    | 5736  |
| 7     | 6554  | 16    | 5999  | 25    | 7017  |
| 8     | 7638  | 17    | 7152  |       |   |
| 9     | 8523  | 18    | 8305  |       |   |

## Specific Gravity of Barium Iodide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 285.)

$g\%$  = gms. of  $\text{BaI}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 5     | 1.045   | 25    | 1.265   | 45    | 1.596   |
| 10    | .091  | 30    | .333  | 50    | .704  |
| 15    | .143  | 35    | .412  | 55    | .825  |
| 20    | .201  | 40    | .495  | 60    | .970  |

## Specific Gravity of Borax Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 473.)

$g\%$  = gms. of  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$  in 100 gms. of solution.

$G\%$  = gms. of  $\text{Na}_2\text{B}_4\text{O}_7$  in 100 gms. of solution.

| $g\%$ | $G\%$  | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $G\%$  | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ |
|-------|--------|---|-------|--------|---|
| 1     | 0.5288 | 1.0049  | 4     | 2.1152 | 1.0199  |
| 2     | 1.0576 | .099  | 5     | 2.6439 | .249  |
| 3     | 1.5864 | .149  | 6     | 3.1727 | .299  |

## Specific Gravity of Boric Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 473.)

$g\%$  = gms. of  $\text{H}_3\text{BO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ |
|-------|---|-------|---|
| 1     | 1.0034  | 3     | 1.0106  |
| 2     | 1.0069  | 4     | 1.0147  |

## Specific Gravity of Cadmium Bromide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 285.)

$g\%$  = gms. of  $\text{CdBr}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 5     | 1.043   | 25    | 1.260   | 45    | 1.578   |
| 10    | .090  | 30    | .326  | 50    | .680  |
| 15    | .141  | 35    | .400  |       |   |
| 20    | .199  | 40    | .481  |       |   |

## Specific Gravity of Cadmium Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 283.)

$g\%$  = gms. of  $\text{CdCl}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ |
|-------|---|-------|---|
| 5     | 1.045   | 35    | 1.396   |
| 10    | 1.089   | 40    | 1.472   |
| 15    | 1.140   | 45    | 1.561   |
| 20    | 1.195   | 50    | 1.656   |
| 25    | 1.256   | 55    | 1.765   |
| 30    | 1.321   | 60    | 1.890   |

## Special Gravity of Cadmium Iodide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 285.)

$g\%$  = gms. of  $\text{CdI}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 5     | 1.044   | 25    | 1.253   | 45    | 1.575   |
| 10    | .088  | 30    | .319  | 50    | .680  |
| 15    | .138  | 35    | .395  |       |   |
| 20    | .194  | 40    | .476  |       |   |

## Specific Gravity of Calcium Acetate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, 27, 313.)

$g\%$  = gms. of  $\begin{smallmatrix} \text{CH}_3\text{COO} \\ \text{CH}_3\text{COO} \end{smallmatrix} > \text{Ca}$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.0051  | 11    | 1.0582  | 21    | 1.1105  |
| 2     | 103   | 12    | 634   | 22    | 159   |
| 3     | 155   | 13    | 686   | 23    | 213   |
| 4     | 207   | 14    | 739   | 24    | 267   |
| 5     | 260   | 15    | 792   | 25    | 321   |
| 6     | 313   | 16    | 843   | 26    | 375   |
| 7     | 367   | 17    | 895   | 27    | 430   |
| 8     | 421   | 18    | 947   | 28    | 484   |
| 9     | 475   | 19    | 999   | 29    | 539   |
| 10    | 530   | 20    | 1.1051  | 30    | 594   |

## Specific Gravity of Calcium Bromide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 285.)

$g\%$  = gms. of  $\text{CaBr}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 5     | 1.044   | 25    | 1.252   | 45    | 1.549   |
| 10    | .089  | 30    | .315  | 50    | .641  |
| 15    | .139  | 35    | .385  |       |   |
| 20    | .194  | 40    | .461  |       |   |

## Density of Calcium Chloride Solutions.

(Pickering, 1894.)

$g\%$  = gms. of  $\text{CaCl}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{17.9^\circ\text{C.}}{4^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.9^\circ\text{C.}}{4^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.9^\circ\text{C.}}{4^\circ\text{C.}}}$ |
|-------|--|-------|--|-------|--|
| 1     | 1.007  | 17    | 1.150  | 31    | 1.294  |
| 3     | 24   | 19    | 69   | 33    | 1.316  |
| 5     | 41   | 21    | 89   | 35    | 38   |
| 7     | 58   | 23    | 1.209  | 37    | 61   |
| 9     | 76   | 25    | 29   | 39    | 84   |
| 11    | 94   | 27    | 50   | 41    | 1.406  |
| 13    | 1.112  | 29    | 72   | 43    | 29   |
| 15    | 31   |       |  |       |  |

## Specific Gravity of Chromic Acid Solutions.

(Zettnow, *Pogg. Ann.*, 1871, **143**, 474.)

$g\%$  = gms. of  $\text{CrO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19^\circ\text{C.}}{4^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19^\circ\text{C.}}{4^\circ\text{C.}}}$ |
|-------|--|-------|--|
| 8.25  | 1.059  | 31.8  | 1.203  |
| 8.8   | .067   | 32.6  | .219   |
| 12.3  | .096   | 37.8  | .345   |
| 19.3  | .157   | 62.2  | .702   |

## Specific Gravity of Chromium Sulphate Solutions

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 494.)

$g\%$  = gms. of  $\text{Cr}_2(\text{SO}_4)_3$  in 100 gms. of solution.

Violet modification.

Green modification.

| $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ |
|-------|---|-------|---|
| 2.74  | 1.0275  | 5.48  | 1.0510  |
| 5.48  | .0560   | 10.96 | .1070   |
| 10.96 | .1150   | 16.44 | .1680   |
| 16.44 | .1785   | 21.92 | .2340   |
| 21.92 | .2480   | 27.40 | .3055   |
| 27.40 | .3250   | 32.88 | .3825   |
|       |   | 38.36 | .4650   |
|       |   | 43.84 | .5530   |

## Specific Gravity of Citric Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 295.)

$g\%$  = gms. of  $\text{C}_6\text{O}_7\text{H}_8, \text{H}_2\text{O}$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 2     | 1.0074  | 26    | 1.1060  | 50    | 1.2204  |
| 4     | 149   | 28    | 152   | 52    | 307   |
| 6     | 227   | 30    | 244   | 54    | 410   |
| 8     | 309   | 32    | 333   | 56    | 514   |
| 10    | 392   | 34    | 422   | 58    | 627   |
| 12    | 470   | 36    | 515   | 60    | 738   |
| 14    | 549   | 38    | 612   | 62    | 849   |
| 16    | 632   | 40    | 709   | 64    | 960   |
| 18    | 718   | 42    | 814   | 66    | 1.3071  |
| 20    | 805   | 44    | 899   |       |   |
| 22    | 889   | 46    | 998   |       |   |
| 24    | 972   | 48    | 1.2103  |       |   |

## Specific Gravity of Cobalt Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 306.)

$g\%$  = gms. of  $\text{CoCl}_2$  in 100 gms. of solution.

| $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ | $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ | $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.0099  | 10    | 1.0997  | 18    | 1.1977  |
| 2     | 198   | 11    | 1.1112  | 19    | 1.2110  |
| 3     | 297   | 12    | 228   | 20    | 245   |
| 4     | 396   | 13    | 344   | 21    | 396   |
| 5     | 496   | 14    | 460   | 22    | 547   |
| 6     | 595   | 15    | 579   | 23    | 698   |
| 7     | 695   | 16    | 711   | 24    | 849   |
| 8     | 795   | 17    | 844   | 25    | 1.3002  |
| 9     | 895   |       |   |       |   |

## Specific Gravity of Copper Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 306.)

$g\%$  = gms. of  $\text{CuCl}_2$  in 100 gms. of solution.

| $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ | $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ | $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ | $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|-------|---|
| 1     | 1.0091  | 11    | 1.1049  | 21    | 1.2362  | 31    | 1.3784  |
| 2     | 182   | 12    | 178   | 22    | 501   | 32    | 950   |
| 3     | 273   | 13    | 307   | 23    | 640   | 33    | 1.4116  |
| 4     | 364   | 14    | 436   | 24    | 779   | 34    | 287   |
| 5     | 455   | 15    | 565   | 25    | 918   | 35    | 447   |
| 6     | 548   | 16    | 696   | 26    | 1.3058  | 36    | 615   |
| 7     | 641   | 17    | 827   | 27    | 198   | 37    | 782   |
| 8     | 734   | 18    | 958   | 28    | 338   | 38    | 949   |
| 9     | 827   | 19    | 1.2089  | 29    | 478   | 39    | 1.5116  |
| 10    | 920   | 20    | 223   | 30    | 618   | 40    | 284   |

## Specific Gravity of Copper Nitrate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 310.)

$g\%$  = gms. of  $\text{Cu}(\text{NO}_3)_2$  in 100 gms. of solution.

| $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ | $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ | $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ | $g\%$ | $S_{17.5^\circ\text{C.}}^{17.5^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|-------|---|
| 1     | 1.0090  | 13    | 1.1242  | 25    | 1.2644  | 37    | 1.4274  |
| 2     | 180   | 14    | 342   | 26    | 775   | 38    | 424   |
| 3     | 270   | 15    | 442   | 27    | 906   | 39    | 574   |
| 4     | 360   | 16    | 561   | 28    | 1.3057  | 40    | 724   |
| 5     | 452   | 17    | 680   | 29    | 168   | 41    | 894   |
| 6     | 550   | 18    | 799   | 30    | 299   | 42    | 1.5064  |
| 7     | 648   | 19    | 918   | 31    | 432   | 43    | 234   |
| 8     | 746   | 20    | 1.2037  | 32    | 575   | 44    | 404   |
| 9     | 844   | 21    | 158   | 33    | 708   | 45    | 576   |
| 10    | 942   | 22    | 279   | 34    | 841   |       |   |
| 11    | 1.1042  | 23    | 400   | 35    | 974   |       |   |
| 12    | 142   | 24    | 521   | 36    | 1.4124  |       |   |

## Specific Gravity of Copper Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 288.)

$G\%$  = gms.  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  in 100 gms. of solution.

$g\%$  = gms. of  $\text{CuSO}_4$  in 100 gms. of solution.

| $G\%$ | $g\%$ | $S_{18^\circ\text{C.}}^{18^\circ\text{C.}}$ | $G\%$ | $g\%$ | $S_{18^\circ\text{C.}}^{18^\circ\text{C.}}$ |
|-------|-------|---|-------|-------|---|
| 1     | 0.64  | 1.0063                                      | 16    | 10.23 | 1.1063                                      |
| 2     | 1.28  | 126   | 17    | 10.87 | 135   |
| 3     | 1.92  | 190   | 18    | 11.51 | 208   |
| 4     | 2.56  | 254   | 19    | 12.15 | 281   |
| 5     | 3.20  | 319   | 20    | 12.79 | 354   |
| 6     | 3.84  | 384   | 21    | 13.42 | 427   |
| 7     | 4.48  | 450   | 22    | 14.06 | 501   |
| 8     | 5.11  | 516   | 23    | 14.70 | 585   |
| 9     | 5.75  | 582   | 24    | 15.34 | 659   |
| 10    | 6.39  | 649   | 25    | 15.98 | 738   |
| 11    | 7.03  | 716   | 26    | 16.62 | 817   |
| 12    | 7.67  | 785   | 27    | 17.26 | 898   |
| 13    | 8.31  | 854   | 28    | 17.90 | 980   |
| 14    | 8.95  | 923   | 29    | 18.54 | 1.2063                                      |
| 15    | 9.59  | 993   | 30    | 19.18 | 146   |

NOTE.—Accurate values for density at  $25^\circ\text{C.}$  and  $40^\circ\text{C.}$  of solutions of copper sulphate containing various percentages of sulphuric acid (copper-plating baths, etc.) are given by Holler and Peffer, *J. Amer. Chem. Soc.*, 1916, **38**, 1021.

## Density of Dextrose Solutions.

(Jackson, *Bull. Bureau of Standards*, 1916, **13**, 633, at 20°C.;  
Tollens, *Berichte*, 1896, **9**, 1537, at 17.5°C.)

$g\%$  = gms. of dextrose in 100 gms. of solution.

| $g\%$ | $S_{4^{\circ}\text{C.}}^{20^{\circ}\text{C.}}$ | $g\%$ | $S_{4^{\circ}\text{C.}}^{20^{\circ}\text{C.}}$ | $g\%$ | $S_{4^{\circ}\text{C.}}^{17.5^{\circ}\text{C.}}$ |
|-------|--|-------|--|-------|--|
| 4     | 1.01378  | 18    | 1.07116  | 10    | 1.037  |
| 6     | .02164   | 20    | .07981   | 20    | .080   |
| 8     | .02961   | 22    | .08857   | 30    | .126   |
| 10    | .03769   | 24    | .09744   | 40    | .173   |
| 12    | .04589   | 26    | .10643   | 50    | .222   |
| 14    | .05420   | 28    | .11553   | 60    | .273   |
| 16    | .06262   | 30    | .12475   | 70    | .325   |
|       |  |       |  | 80    | .378   |

## Specific Gravity of Ferric Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 306.)

$g\%$  = gms. of  $\text{FeCl}_3$  in 100 gms. of solution.

| $g\%$ | $S_{17.5^{\circ}\text{C.}}^{17.5^{\circ}\text{C.}}$ | $g\%$ | $S_{17.5^{\circ}\text{C.}}^{17.5^{\circ}\text{C.}}$ | $g\%$ | $S_{17.5^{\circ}\text{C.}}^{17.5^{\circ}\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.008   | 21    | 1.191   | 41    | 1.428   |
| 2     | 16  | 22    | 1.202   | 42    | 41  |
| 3     | 25  | 23    | 12  | 43    | 54  |
| 4     | 33  | 24    | 23  | 44    | 69  |
| 5     | 42  | 25    | 34  | 45    | 81  |
| 6     | 51  | 26    | 45  | 46    | 94  |
| 7     | 60  | 27    | 56  | 47    | 1.507   |
| 8     | 69  | 28    | 68  | 48    | 20  |
| 9     | 78  | 29    | 80  | 49    | 33  |
| 10    | 87  | 30    | 92  | 50    | 47  |
| 11    | 95  | 31    | 1.304   | 51    | 60  |
| 12    | 1.104   | 32    | 16  | 52    | 73  |
| 13    | 13  | 33    | 28  | 53    | 87  |
| 14    | 23  | 34    | 40  | 54    | 1.600   |
| 15    | 31  | 35    | 52  | 55    | 12  |
| 16    | 40  | 36    | 64  | 56    | 24  |
| 17    | 50  | 37    | 76  | 57    | 36  |
| 18    | 60  | 38    | 90  | 58    | 48  |
| 19    | 70  | 39    | 1.403   | 59    | 59  |
| 20    | 80  | 40    | 15  | 60    | 70  |



## Specific Gravity of Ferric Nitrate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 310.)

g% = gms. of  $\text{Fe}_2(\text{NO}_3)_2$  in 100 gms. of solution.

| g% | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | g% | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | g% | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | g% | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ |
|----|---|----|---|----|---|----|---|
| 1  | 1.0080  | 18 | 1.1440  | 35 | 1.3164  | 52 | 1.5272  |
| 2  | 160   | 19 | 526   | 36 | 280   | 53 | 422   |
| 3  | 240   | 20 | 612   | 37 | 396   | 54 | 572   |
| 4  | 320   | 21 | 712   | 38 | 512   | 55 | 722   |
| 5  | 398   | 22 | 812   | 39 | 628   | 56 | 892   |
| 6  | 472   | 23 | 912   | 40 | 746   | 57 | 1.6062  |
| 7  | 546   | 24 | 1.2012  | 41 | 864   | 58 | 232   |
| 8  | 620   | 25 | 110   | 42 | 982   | 59 | 402   |
| 9  | 694   | 26 | 212   | 43 | 1.4100  | 60 | 572   |
| 10 | 770   | 27 | 314   | 44 | 218   | 61 | 764   |
| 11 | 852   | 28 | 416   | 45 | 338   | 62 | 956   |
| 12 | 934   | 29 | 518   | 46 | 465   | 63 | 1.7148  |
| 13 | 1.1016  | 30 | 622   | 47 | 592   | 64 | 340   |
| 14 | 098   | 31 | 730   | 48 | 719   | 65 | 532   |
| 15 | 182   | 32 | 838   | 49 | 846   |    |   |
| 16 | 268   | 33 | 946   | 50 | 972   |    |   |
| 17 | 354   | 34 | 1.3054  | 51 | 1.5122  |    |   |

## Specific Gravity of Ferric Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 308.)

g% = gms. of  $\text{Fe}_2(\text{SO}_4)_3$  in 100 gms. of solution.

| g% | $S_{\frac{18^\circ\text{C.}}{18^\circ\text{C.}}}$ | g% | $S_{\frac{18^\circ\text{C.}}{18^\circ\text{C.}}}$ | g% | $S_{\frac{18^\circ\text{C.}}{18^\circ\text{C.}}}$ | g% | $S_{\frac{18^\circ\text{C.}}{18^\circ\text{C.}}}$ |
|----|---|----|---|----|---|----|---|
| 1  | 1.008   | 12 | 1.118   | 23 | 1.245   | 34 | 1.395   |
| 2  | 17  | 13 | 29  | 24 | 58  | 35 | 1.411   |
| 3  | 27  | 14 | 40  | 25 | 71  | 36 | 27  |
| 4  | 36  | 15 | 51  | 26 | 84  | 37 | 42  |
| 5  | 46  | 16 | 62  | 27 | 97  | 38 | 58  |
| 6  | 57  | 17 | 73  | 28 | 1.310   | 39 | 74  |
| 7  | 67  | 18 | 84  | 29 | 23  | 40 | 90  |
| 8  | 77  | 19 | 96  | 30 | 37  | 41 | 1.506   |
| 9  | 87  | 20 | 1.208   | 31 | 51  | 42 | 23  |
| 10 | 97  | 21 | 20  | 32 | 65  | 43 | 40  |
| 11 | 1.107   | 22 | 32  | 33 | 80  | 44 | 57  |

## Specific Gravity of Ferrous Ammonium Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 286.)

$g\%$  = gms. of  $\text{FeSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$  in 100 gms. of solution.

| $g\%$ | $S_{19^\circ\text{C.}}^{19^\circ\text{C.}}$ | $g\%$ | $S_{19^\circ\text{C.}}^{19^\circ\text{C.}}$ | $g\%$ | $S_{19^\circ\text{C.}}^{19^\circ\text{C.}}$ | $g\%$ | $S_{19^\circ\text{C.}}^{19^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|-------|---|
| 1     | 1.006                                       | 9     | 1.054                                       | 17    | 1.104                                       | 25    | 1.156                                       |
| 2     | 13  | 10    | 60  | 18    | 10  | 26    | 64  |
| 3     | 18  | 11    | 66  | 19    | 16  | 27    | 71  |
| 4     | 24  | 12    | 73  | 20    | 24  | 28    | 79  |
| 5     | 30  | 13    | 80  | 21    | 30  | 29    | 85  |
| 6     | 36  | 14    | 85  | 22    | 36  | 30    | 93  |
| 7     | 42  | 15    | 92  | 23    | 43  |       |   |
| 8     | 47  | 16    | 97  | 24    | 50  |       |   |

## Specific Gravity of Ferrous Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 286.)

$G\%$  = gms. of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  in 100 gms. of solution.

$g\%$  = gms. of  $\text{FeSO}_4$  in 100 gms. of solution.

| $G\%$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $G\%$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ |
|-------|-------|---|-------|-------|---|
| 1     | 0.55  | 1.005                                       | 21    | 11.48 | 1.118                                       |
| 2     | 1.09  | 11  | 22    | 12.03 | 25  |
| 3     | 1.64  | 16  | 23    | 12.58 | 31  |
| 4     | 2.19  | 21  | 24    | 13.12 | 37  |
| 5     | 2.73  | 27  | 25    | 13.67 | 43  |
| 6     | 3.28  | 32  | 26    | 14.22 | 49  |
| 7     | 3.83  | 37  | 27    | 14.76 | 55  |
| 8     | 4.37  | 43  | 28    | 15.31 | 61  |
| 9     | 4.72  | 48  | 29    | 15.86 | 68  |
| 10    | 5.47  | 54  | 30    | 16.40 | 74  |
| 11    | 6.01  | 59  | 31    | 16.95 | 80  |
| 12    | 6.56  | 65  | 32    | 17.50 | 87  |
| 13    | 7.11  | 71  | 33    | 18.04 | 93  |
| 14    | 7.65  | 77  | 34    | 18.59 | 1.200                                       |
| 15    | 8.20  | 82  | 35    | 19.14 | 06  |
| 16    | 8.75  | 88  | 36    | 19.68 | 13  |
| 17    | 9.30  | 94  | 37    | 20.23 | 19  |
| 18    | 9.84  | 1.100                                       | 38    | 20.78 | 26  |
| 19    | 10.39 | 06  | 39    | 21.32 | 32  |
| 20    | 10.94 | 12  | 40    | 21.87 | 39  |

## Specific Gravity of Formaldehyde Solutions.

(Davis, *J.S. Chem. Ind.*, 1897, **16**, 502.)

$g\%$  = gms. of HCHO in 100 gms. of solution

| $g\%$ | $S_{4^{\circ}\text{C.}}^{60^{\circ}\text{F.}}$ | $g\%$ | $S_{4^{\circ}\text{C.}}^{60^{\circ}\text{F.}}$ | $g\%$ | $S_{4^{\circ}\text{C.}}^{60^{\circ}\text{F.}}$ | $g\%$ | $S_{4^{\circ}\text{C.}}^{60^{\circ}\text{F.}}$ |
|-------|--|-------|--|-------|--|-------|--|
| 5     | 1.015  | 15    | 1.037  | 25    | 1.066  | 35    | 1.103  |
| 10    | 24   | 20    | 52   | 30    | 82   | 40    | 24   |

## Density of Formic Acid Solutions.

(Richardson and Kramer, *Ber. Chem. Ges.*, 1874, **7**, 1495, and 1876, **9**, 1929.)

$g\%$  = gms. of HCOOH in 100 gms. of solution.

| $g\%$ | $S_{4^{\circ}\text{C.}}^{20^{\circ}\text{C.}}$ | $g\%$ | $S_{4^{\circ}\text{C.}}^{20^{\circ}\text{C.}}$ | $g\%$ | $S_{4^{\circ}\text{C.}}^{20^{\circ}\text{C.}}$ |
|-------|--|-------|--|-------|--|
| 1     | 1.0020   | 38    | 1.0920   | 80    | 1.1861   |
| 2     | 045  | 42    | 1.1016   | 82    | 897  |
| 4     | 094  | 46    | 109  | 84    | 930  |
| 6     | 1.0142   | 50    | 208  | 86    | 977  |
| 8     | 197  | 54    | 296  | 88    | 1.2013   |
| 10    | 247  | 58    | 382  | 90    | 045  |
| 14    | 346  | 62    | 474  | 92    | 079  |
| 18    | 442  | 66    | 566  | 94    | 118  |
| 22    | 538  | 70    | 656  | 96    | 159  |
| 26    | 634  | 74    | 753  | 98    | 184  |
| 30    | 730  | 78    | 819  | 100   | 213  |
| 34    | 824  |       |  |       |  |

# Specific Gravity of Mixtures of Glycerin and Water.

(Skalweit, *Repertor. d. Analyt. Chemie.*, 1885, 5, 18.)

$g\%$  = gms. of glycerin in 100 gms. of mixture.

| $g\%$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ |
|-------|---|-------|---|-------|---|-------|---|
| 0     | 1.0000  | 26    | 1.0646  | 51    | 1.1318  | 76    | 1.2017  |
| 1     | 024   | 27    | 672   | 52    | 346   | 77    | 044   |
| 2     | 048   | 28    | 698   | 53    | 374   | 78    | 071   |
| 3     | 072   | 29    | 724   | 54    | 402   | 79    | 098   |
| 4     | 096   | 30    | 750   | 55    | 430   | 80    | 125   |
| 5     | 120   | 31    | 777   | 56    | 458   | 81    | 152   |
| 6     | 144   | 32    | 804   | 57    | 486   | 82    | 179   |
| 7     | 168   | 33    | 831   | 58    | 514   | 83    | 206   |
| 8     | 192   | 34    | 858   | 59    | 542   | 84    | 233   |
| 9     | 216   | 35    | 885   | 60    | 570   | 85    | 260   |
| 10    | 240   | 36    | 912   | 61    | 599   | 86    | 287   |
| 11    | 265   | 37    | 939   | 62    | 628   | 87    | 314   |
| 12    | 290   | 38    | 966   | 63    | 657   | 88    | 341   |
| 13    | 315   | 39    | 993   | 64    | 686   | 89    | 368   |
| 14    | 340   | 40    | 1.1020  | 65    | 715   | 90    | 395   |
| 15    | 365   | 41    | 047   | 66    | 743   | 91    | 421   |
| 16    | 390   | 42    | 074   | 67    | 771   | 92    | 447   |
| 17    | 415   | 43    | 101   | 68    | 799   | 93    | 473   |
| 18    | 440   | 44    | 128   | 69    | 827   | 94    | 499   |
| 19    | 465   | 45    | 155   | 70    | 855   | 95    | 525   |
| 20    | 490   | 46    | 182   | 71    | 882   | 96    | 550   |
| 21    | 516   | 47    | 209   | 72    | 909   | 97    | 575   |
| 22    | 542   | 48    | 236   | 73    | 936   | 98    | 600   |
| 23    | 568   | 49    | 263   | 74    | 963   | 99    | 625   |
| 24    | 594   | 50    | 290   | 75    | 990   | 100   | 650   |
| 25    | 620   |       |   |       |   |       |   |

## Density of Hydriodic Acid Solutions.

(Perkin, *Journ. Chem. Soc.*, 1889, 55, 680.)

$g\%$  = gms. of HI in 100 gms. of solution.

| $g\%$ | $S_{4^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | $S_{4^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ |
|-------|--|-------|--|
| 20.77 | 1.1758   | 56.78 | 1.6998   |
| 31.77 | 1.2962   | 61.97 | 1.8218   |
| 42.7  | 1.4489   |       |  |

## Specific Gravity of Hydrobromic Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 316.)

$g\%$  = gms. of HBr in 100 gms. of solution.

| $g\%$ | $S_{14^{\circ}\text{C.}}^{14^{\circ}\text{C.}}$ | $g\%$ | $S_{14^{\circ}\text{C.}}^{14^{\circ}\text{C.}}$ | $g\%$ | $S_{14^{\circ}\text{C.}}^{14^{\circ}\text{C.}}$ | $g\%$ | $S_{14^{\circ}\text{C.}}^{14^{\circ}\text{C.}}$ | $g\%$ | $S_{14^{\circ}\text{C.}}^{14^{\circ}\text{C.}}$ |
|-------|---|-------|---|-------|---|-------|---|-------|---|
| 1     | 1.007   | 11    | 1.081   | 21    | 1.167   | 31    | 1.268   | 41    | 1.389   |
| 2     | 1.014   | 12    | 1.089   | 22    | 1.176   | 32    | 1.279   | 42    | 1.403   |
| 3     | 1.021   | 13    | 1.097   | 23    | 1.186   | 33    | 1.290   | 43    | 1.417   |
| 4     | 1.028   | 14    | 1.106   | 24    | 1.196   | 34    | 1.302   | 44    | 1.431   |
| 5     | 1.035   | 15    | 1.114   | 25    | 1.206   | 35    | 1.314   | 45    | 1.445   |
| 6     | 1.043   | 16    | 1.122   | 26    | 1.215   | 36    | 1.326   | 46    | 1.459   |
| 7     | 1.050   | 17    | 1.131   | 27    | 1.225   | 37    | 1.338   | 47    | 1.473   |
| 8     | 1.058   | 18    | 1.140   | 28    | 1.235   | 38    | 1.351   | 48    | 1.487   |
| 9     | 1.065   | 19    | 1.149   | 29    | 1.246   | 39    | 1.363   | 49    | 1.502   |
| 10    | 1.073   | 20    | 1.158   | 30    | 1.257   | 40    | 1.376   |       |   |

## Density of Hydrochloric Acid Solutions.

(Lunge and Marchlewski *Z. angew. Chem.*, 1891, **4**, 133.)

$g\%$  = gms. of HCl in 100 gms. of solution.

G = gms. of HCl in 1 litre of solution.

| $S_{4^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | G.  | $S_{4^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | G.  |
|--|-------|-----|--|-------|-----|
| 1.000  | 0.16  | 1.6 | 1.105  | 20.97 | 232 |
| 1.005  | 1.15  | 12  | 1.110  | 21.92 | 243 |
| 1.010  | 2.14  | 22  | 1.115  | 22.86 | 255 |
| 1.015  | 3.12  | 32  | 1.120  | 23.82 | 267 |
| 1.020  | 4.13  | 42  | 1.125  | 24.78 | 278 |
| 1.025  | 5.15  | 53  | 1.130  | 25.75 | 291 |
| 1.030  | 6.15  | 64  | 1.135  | 26.70 | 303 |
| 1.035  | 7.15  | 74  | 1.140  | 27.66 | 315 |
| 1.040  | 8.16  | 85  | 1.145  | 28.61 | 328 |
| 1.045  | 9.16  | 96  | 1.150  | 29.57 | 340 |
| 1.050  | 10.17 | 107 | 1.155  | 30.55 | 353 |
| 1.055  | 11.18 | 118 | 1.160  | 31.52 | 366 |
| 1.060  | 12.19 | 129 | 1.165  | 32.49 | 379 |
| 1.065  | 13.19 | 141 | 1.170  | 33.46 | 392 |
| 1.070  | 14.17 | 152 | 1.175  | 34.42 | 404 |
| 1.075  | 15.16 | 163 | 1.180  | 35.39 | 418 |
| 1.080  | 16.15 | 174 | 1.185  | 36.31 | 430 |
| 1.085  | 17.13 | 186 | 1.190  | 37.23 | 443 |
| 1.090  | 18.11 | 197 | 1.195  | 38.16 | 456 |
| 1.095  | 19.06 | 209 | 1.200  | 39.11 | 469 |
| 1.100  | 20.01 | 220 |  |       |     |

## Change in Density of Hydrochloric Acid Solutions with Temperature.

$g\%$  = gms. of HCl in 100 gms. of solution.  
 $C$  = change in density per  $^{\circ}\text{C}$ . at room temperature.

| $g\%$ | $C$ .  | $g\%$ | $C$ .  | $g\%$ | $C$ .  |
|-------|--------|-------|--------|-------|--------|
| 5     | 0.0001 | 20    | 0.0004 | 35    | 0.0006 |
| 10    | 0.0002 | 25    | 0.0005 | 40    | 0.0007 |
| 15    | 0.0003 | 30    | 0.0006 |       |        |

## Density of Hydrofluoric Acid Solutions.

(Hill and Sirkar, *Proc. Roy. Soc.*, 1909, A, **83**, 130.)

$g\%$  = gms. of HF in 100 gms. of solution.

| $g\%$ | $S_{\frac{0^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{0^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{0^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 6.1   | 1.028   | 56.7  | 1.230   | 88.7  | 1.208   |
| 12.1  | 1.047   | 63.2  | 1.247   | 91.0  | 1.164   |
| 21.4  | 1.085   | 73.8  | 1.261   | 95.0  | 1.082   |
| 28.4  | 1.110   | 76.9  | 1.262   | 100.0 | 1.0005  |
| 45.3  | 1.172   | 85.1  | 1.232   |       |   |

## Specific Gravity of Hydrofluosilicic Acid.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 316.)

$g\%$  = gms. of  $\text{H}_2\text{SiF}_6$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{17.5^{\circ}\text{C.}}{17.5^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^{\circ}\text{C.}}{17.5^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^{\circ}\text{C.}}{17.5^{\circ}\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 2     | 1.0161  | 14    | 1.1190  | 26    | 1.2335  |
| 4     | 324   | 16    | 373   | 28    | 537   |
| 6     | 491   | 18    | 559   | 30    | 742   |
| 8     | 661   | 20    | 748   | 32    | 951   |
| 10    | 834   | 22    | 941   | 34    | 1.3162  |
| 12    | 1.1011  | 24    | 1.2136  |       |   |

## Specific Gravity of Lead Acetate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$  = gms. of  $(\text{CH}_3\text{COO})_2\text{Pb} \cdot 3\text{H}_2\text{O}$  in 100 gms. of solution.

| $g\%$ | $\frac{S_{15^\circ\text{C.}}}{15^\circ\text{C.}}$ | $g\%$ | $\frac{S_{15^\circ\text{C.}}}{15^\circ\text{C.}}$ | $g\%$ | $\frac{S_{15^\circ\text{C.}}}{15^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.0064  | 18    | 1.1234  | 35    | 1.2669  |
| 2     | 127   | 19    | 309   | 36    | 768   |
| 3     | 191   | 20    | 384   | 37    | 867   |
| 4     | 255   | 21    | 464   | 38    | 966   |
| 5     | 319   | 22    | 544   | 39    | 1.3064  |
| 6     | 386   | 23    | 624   | 40    | 163   |
| 7     | 453   | 24    | 704   | 41    | 269   |
| 8     | 520   | 25    | 784   | 42    | 376   |
| 9     | 587   | 26    | 869   | 43    | 482   |
| 10    | 654   | 27    | 955   | 44    | 588   |
| 11    | 725   | 28    | 1.2040  | 45    | 695   |
| 12    | 796   | 29    | 126   | 46    | 810   |
| 13    | 867   | 30    | 211   | 47    | 925   |
| 14    | 939   | 31    | 303   | 48    | 1.4041  |
| 15    | 1.1010  | 32    | 395   | 49    | 156   |
| 16    | 084   | 33    | 486   | 50    | 271   |
| 17    | 159   | 34    | 578   |       |   |

## Specific Gravity of Lead Nitrate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)

$g\%$  = gms. of  $\text{Pb}(\text{NO}_3)_2$  in 100 gms. of solution.

| $g\%$ | $\frac{S_{17.5^\circ\text{C.}}}{17.5^\circ\text{C.}}$ | $g\%$ | $\frac{S_{17.5^\circ\text{C.}}}{17.5^\circ\text{C.}}$ | $g\%$ | $\frac{S_{17.5^\circ\text{C.}}}{17.5^\circ\text{C.}}$ | $g\%$ | $\frac{S_{17.5^\circ\text{C.}}}{17.5^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|-------|---|
| 1     | 1.0080  | 11    | 1.0963  | 21    | 1.2016  | 31    | 1.3276  |
| 2     | 163   | 12    | 1.1059  | 22    | 132   | 32    | 416   |
| 3     | 247   | 13    | 157   | 23    | 251   | 33    | 558   |
| 4     | 331   | 14    | 257   | 24    | 372   | 34    | 702   |
| 5     | 416   | 15    | 359   | 25    | 495   | 35    | 848   |
| 6     | 502   | 16    | 463   | 26    | 620   | 36    | 996   |
| 7     | 591   | 17    | 569   | 27    | 747   | 37    | 1.4146  |
| 8     | 682   | 18    | 677   | 28    | 876   |       |   |
| 9     | 775   | 19    | 788   | 29    | 1.3007  |       |   |
| 10    | 869   | 20    | 902   | 30    | 140   |       |   |

## Specific Gravity of Magnesium Bromide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 285.)

$g\%$  = gms. of  $\text{MgBr}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 5     | 1.043   | 25    | 1.247   | 40    | 1.451   |
| 10    | 1.087   | 30    | 1.310   | 45    | 1.535   |
| 15    | 1.137   | 35    | 1.377   | 50    | 1.625   |
| 20    | 1.191   |       |   |       |   |

## Specific Gravity of Magnesium Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 281.)

$g\%$  = gms. of  $\text{MgCl}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.00844   | 13    | 1.11300   | 25    | 1.22737   |
| 2     | 1689  | 14    | 2203  | 26    | 3777  |
| 3     | 2533  | 15    | 3106  | 27    | 4817  |
| 4     | 3378  | 16    | 4045  | 28    | 5857  |
| 5     | 4222  | 17    | 4984  | 29    | 6897  |
| 6     | 5096  | 18    | 5922  | 30    | 7937  |
| 7     | 5970  | 19    | 6861  | 31    | 9029  |
| 8     | 6844  | 20    | 7800  | 32    | 1.30121   |
| 9     | 7718  | 21    | 8787  | 33    | 1213  |
| 10    | 8592  | 22    | 9775  | 34    | 2306  |
| 11    | 9495  | 23    | 1.20762   | 35    | 3397  |
| 12    | 1.10398   | 24    | 1750  |       |   |

## Specific Gravity of Magnesium Iodide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 258.)

$g\%$  = gms. of  $\text{MgI}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 5     | 1.043   | 25    | 1.254   | 45    | 1.568   |
| 10    | 1.088   | 30    | 1.320   | 50    | 1.668   |
| 15    | 1.139   | 35    | 1.395   | 55    | 1.780   |
| 20    | 1.194   | 40    | 1.474   | 60    | 1.915   |



## Density of Magnesium Sulphate Solutions.

(Barnes and Scott, *Journ. Phys. Chem.*, 1898, **2**, 536.)

$g\%$  = gms. of  $\text{MgSO}_4$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{18.2^\circ\text{C.}}{4^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{18.2^\circ\text{C.}}{4^\circ\text{C.}}}$ |
|-------|--|-------|--|
| 2.01  | 1.0187   | 18.41 | 1.1950   |
| 8.08  | 1.0803   | 21.60 | 1.2330   |
| 11.29 | 1.1147   | 24.53 | 1.2693   |
| 12.63 | 1.1292   | 25.91 | 1.2860   |
| 13.79 | 1.1423   | 26.25 | 1.2903   |

## Specific Gravity of Manganese Chloride Solutions

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 476.)

$g\%$  = gms. of  $\text{MnCl}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 5     | 1.045   | 20    | 1.189   | 35    | 1.372   |
| 10    | 1.091   | 25    | 1.245   | 40    | 1.443   |
| 15    | 1.138   | 30    | 1.306   | 45    | 1.514   |

## Specific Gravity of Manganese Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 478.)

$g\%$  = gms. of  $\text{MnSO}_4$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 5     | 1.0500  | 15    | 1.1605  | 25    | 1.2870  |
| 10    | 1.1035  | 20    | 1.2215  | 30    | 1.3575  |

## Density of Mercuric Chloride Solution.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 306.)  
 $g\%$  = gms. of  $\text{HgCl}_2$  in 100 gms. of solution.

| $g\%$                     | $S_{\frac{20^\circ\text{C.}}{4^\circ\text{C.}}}$ | $g\%$                        | $S_{\frac{15^\circ\text{C.}}{4^\circ\text{C.}}}$ |
|---------------------------|--|------------------------------|--|
| 1                         | 1.0072   | 8                            | 1.071  |
| 2                         | 148  | 9                            | 81   |
| 3                         | 236  | 10                           | 95   |
| 4                         | 323  | 11                           | 1.103  |
| 5                         | 411  | 12                           | 15   |
|                           |  | 13                           | 27   |
| (From Schröder's values.) |  | (From Mendelejeff's values.) |  |

## Specific Gravity of Nickel Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 306.)  
 $g\%$  = gms. of  $\text{NiCl}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.0099  | 10    | 1.0997  | 18    | 1.1977  |
| 2     | 198   | 11    | 1.1112  | 19    | 1.2110  |
| 3     | 297   | 12    | 228   | 20    | 245   |
| 4     | 396   | 13    | 344   | 21    | 396   |
| 5     | 496   | 14    | 460   | 22    | 547   |
| 6     | 595   | 15    | 579   | 23    | 698   |
| 7     | 695   | 16    | 711   | 24    | 849   |
| 8     | 795   | 17    | 844   | 25    | 1.3002  |
| 9     | 895   |       |   |       |   |

## Density of Nickel Sulphate Solutions.

(MacGregor, *Trans. Can.*, 1890, **8**, 19.)  
 and (Klein, *Wied. Ann.*, 1886, **27**, 151.)  
 $g\%$  = gms. of  $\text{NiSO}_4$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{20^\circ\text{C.}}{4^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{18^\circ\text{C.}}{4^\circ\text{C.}}}$ |
|-------|--|-------|--|
| 1.251 | 1.01155  | 7.46  | 1.0379   |
| 2.080 | 1.02046  | 14.38 | 1.0759   |
| 3.963 | 1.04064  | 26.91 | 1.1503   |
|       |  | 38.00 | 1.2219   |

## Density of Nitric Acid Solutions.

(Lunge and Keane, "Technical Methods of Chemical Analysis," 1908, Vol. I, p. 325.)

$g\%$  = gms. of  $\text{HNO}_3$  in 100 gms. of solution.

$G$  = gms. of  $\text{HNO}_3$  in 1 litre of solution.

| $S_{\substack{15^\circ\text{C.} \\ 4^\circ\text{C.}}}$ | $g\%$ | $G.$ | $S_{\substack{15^\circ\text{C.} \\ 4^\circ\text{C.}}}$ | $g\%$ | $G.$ |
|--|-------|------|--|-------|------|
| 1.000  | 0.10  | 1    | 1.170  | 27.88 | 326  |
| 1.005  | 1.00  | 10   | 1.175  | 28.63 | 336  |
| 1.010  | 1.90  | 19   | 1.180  | 29.38 | 347  |
| 1.015  | 2.80  | 28   | 1.185  | 30.13 | 357  |
| 1.020  | 3.70  | 38   | 1.190  | 30.88 | 367  |
| 1.025  | 4.60  | 47   | 1.195  | 31.62 | 378  |
| 1.030  | 5.50  | 57   | 1.200  | 32.36 | 388  |
| 1.035  | 6.38  | 66   | 1.205  | 33.09 | 399  |
| 1.040  | 7.26  | 75   | 1.210  | 33.82 | 409  |
| 1.045  | 8.13  | 85   | 1.215  | 34.55 | 420  |
| 1.050  | 8.99  | 94   | 1.220  | 35.28 | 430  |
| 1.055  | 9.84  | 104  | 1.225  | 36.03 | 441  |
| 1.060  | 10.68 | 113  | 1.230  | 36.78 | 452  |
| 1.065  | 11.51 | 123  | 1.235  | 37.53 | 463  |
| 1.070  | 12.33 | 132  | 1.240  | 38.29 | 475  |
| 1.075  | 13.15 | 141  | 1.245  | 39.05 | 486  |
| 1.080  | 13.95 | 151  | 1.250  | 39.82 | 498  |
| 1.085  | 14.74 | 160  | 1.255  | 40.58 | 509  |
| 1.090  | 15.53 | 169  | 1.260  | 41.34 | 521  |
| 1.095  | 16.32 | 179  | 1.265  | 42.10 | 533  |
| 1.100  | 17.11 | 188  | 1.270  | 42.87 | 544  |
| 1.105  | 17.89 | 198  | 1.275  | 43.64 | 556  |
| 1.110  | 18.67 | 207  | 1.280  | 44.41 | 568  |
| 1.115  | 19.45 | 217  | 1.285  | 45.18 | 581  |
| 1.120  | 20.23 | 227  | 1.290  | 45.95 | 593  |
| 1.125  | 21.00 | 236  | 1.295  | 46.72 | 605  |
| 1.130  | 21.77 | 246  | 1.300  | 47.49 | 617  |
| 1.135  | 22.54 | 256  | 1.305  | 48.26 | 630  |
| 1.140  | 23.31 | 266  | 1.310  | 49.07 | 643  |
| 1.145  | 24.08 | 276  | 1.315  | 49.89 | 656  |
| 1.150  | 24.84 | 285  | 1.320  | 50.71 | 669  |
| 1.155  | 25.60 | 296  | 1.325  | 51.53 | 683  |
| 1.160  | 26.36 | 306  | 1.330  | 52.37 | 697  |
| 1.165  | 27.12 | 316  | 1.335  | 53.22 | 710  |

| $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | G.   | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | G.   |
|--|-------|------|--|-------|------|
| 1.340  | 54.07 | 725  | 1.475  | 84.45 | 1246 |
| 1.345  | 54.93 | 739  | 1.480  | 86.05 | 1274 |
| 1.350  | 55.79 | 753  | 1.485  | 87.70 | 1302 |
| 1.355  | 56.66 | 768  | 1.490  | 89.60 | 1335 |
| 1.360  | 57.57 | 783  | 1.495  | 91.60 | 1369 |
| 1.365  | 58.48 | 798  | 1.500  | 94.09 | 1411 |
| 1.370  | 59.39 | 814  | 1.501  | 94.60 | 1420 |
| 1.375  | 60.30 | 829  | 1.502  | 95.08 | 1428 |
| 1.380  | 61.27 | 846  | 1.503  | 95.55 | 1436 |
| 1.385  | 62.24 | 862  | 1.504  | 96.00 | 1444 |
| 1.390  | 63.23 | 879  | 1.505  | 96.39 | 1451 |
| 1.395  | 64.25 | 896  | 1.506  | 96.76 | 1457 |
| 1.400  | 65.30 | 914  | 1.507  | 97.13 | 1464 |
| 1.405  | 66.40 | 933  | 1.508  | 97.50 | 1470 |
| 1.410  | 67.50 | 952  | 1.509  | 97.84 | 1476 |
| 1.415  | 68.63 | 971  | 1.510  | 98.10 | 1481 |
| 1.420  | 69.80 | 991  | 1.511  | 98.32 | 1486 |
| 1.425  | 70.98 | 1011 | 1.512  | 98.53 | 1490 |
| 1.430  | 72.17 | 1032 | 1.513  | 98.73 | 1494 |
| 1.435  | 73.39 | 1053 | 1.514  | 98.90 | 1497 |
| 1.440  | 74.68 | 1075 | 1.515  | 99.07 | 1501 |
| 1.445  | 75.98 | 1098 | 1.516  | 99.21 | 1504 |
| 1.450  | 77.28 | 1121 | 1.517  | 99.34 | 1507 |
| 1.455  | 78.60 | 1144 | 1.518  | 99.46 | 1510 |
| 1.460  | 79.98 | 1168 | 1.519  | 99.57 | 1512 |
| 1.465  | 81.42 | 1193 | 1.520  | 99.67 | 1515 |
| 1.470  | 82.90 | 1219 |  |       |      |

## Change in Density of Nitric Acid with Temperature.

(Lunge and Keane, *loc. cit.*, p. 327.)

S=approximate specific gravity.

C=fall in density per °C. rise in temperature in the neighbourhood of 15°C.

$$\frac{S_{15^{\circ}\text{C.}}}{4^{\circ}\text{C.}} = \frac{S_{t^{\circ}\text{C.}}}{4^{\circ}} + C(t - 15)$$

| S.             | C.     | S.             | C.     |
|----------------|--------|----------------|--------|
| 1.000 to 1.020 | 0.0001 | 1.281 to 1.310 | 0.0010 |
| 1.021 „ 1.040  | 2      | 1.311 „ 1.350  | 11     |
| 1.041 „ 1.070  | 3      | 1.351 „ 1.365  | 12     |
| 1.071 „ 1.100  | 4      | 1.366 „ 1.400  | 13     |
| 1.101 „ 1.130  | 5      | 1.401 „ 1.435  | 14     |
| 1.131 „ 1.161  | 6      | 1.436 „ 1.490  | 15     |
| 1.162 „ 1.200  | 7      | 1.491 „ 1.500  | 16     |
| 1.201 „ 1.245  | 8      | 1.501 „ 1.520  | 17     |
| 1.246 „ 1.280  | 9      |                |        |

### *Influence of Nitrogen Peroxide on Density of Nitric Acid.*

Bousfield (*J.C.S.*, 1919, 48) and Pascal and Garnier (*Bull. soc. Chim.*, 1919, **25**, 309), who worked by adding liquid  $\text{N}_2\text{O}_4$  to nitric acid (of  $S_{\frac{18}{4}}$  1.5126 and  $S_{\frac{15}{4}}$  1.5130 respectively), both agree in making the increase in specific gravity .0040 per 1%  $\text{N}_2\text{O}_4$  in the mixture for concentrations 5% to 20%  $\text{N}_2\text{O}_4$  and about .0035 per 1%  $\text{N}_2\text{O}_4$  for concentrations lower than 5%. Lunge and Marchlewski, who used acid of  $S_{\frac{15}{4}}$  1.490 and estimated the  $\text{N}_2\text{O}_4$  in it by titration, give corrections increasing from .0030 per 1%  $\text{N}_2\text{O}_4$ , at a concentration of 1%, to .0066 per 1% at concentrations 5% to 12.5%.

### Specific Gravity of Oxalic Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 315.)

g% = gms. of  $\text{C}_2\text{H}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$  in 100 gms. of solution.

| g% | $\frac{S_{17.5^{\circ}\text{C.}}}{17.5^{\circ}\text{C.}}$ | g% | $\frac{S_{17.5^{\circ}\text{C.}}}{17.5^{\circ}\text{C.}}$ | g% | $\frac{S_{17.5^{\circ}\text{C.}}}{17.5^{\circ}\text{C.}}$ |
|----|---|----|---|----|---|
| 1  | 1.0035  | 5  | 1.0175  | 9  | 1.0315  |
| 2  | 070   | 6  | 210   | 10 | 350   |
| 3  | 105   | 7  | 245   | 11 | 385   |
| 4  | 140   | 8  | 280   | 12 | 420   |

## Specific Gravity of Phosphoric Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 292.)

$g\%$  = gms. of  $H_3PO_4$  in 100 gms. of solution.

| $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ | $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ | $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ |
|-------|---------------------------------|-------|---------------------------------|-------|---------------------------------|
| 1     | 1.0054                          | 21    | 1.1262                          | 41    | 1.2731                          |
| 2     | 1.0109                          | 22    | 1.1329                          | 42    | 1.2812                          |
| 3     | 1.0164                          | 23    | 1.1397                          | 43    | 1.2894                          |
| 4     | 1.0220                          | 24    | 1.1465                          | 44    | 1.2976                          |
| 5     | 1.0276                          | 25    | 1.1534                          | 45    | 1.3059                          |
| 6     | 1.0333                          | 26    | 1.1604                          | 46    | 1.3143                          |
| 7     | 1.0390                          | 27    | 1.1674                          | 47    | 1.3227                          |
| 8     | 1.0449                          | 28    | 1.1745                          | 48    | 1.3313                          |
| 9     | 1.0508                          | 29    | 1.1817                          | 49    | 1.3399                          |
| 10    | 1.0567                          | 30    | 1.1889                          | 50    | 1.3486                          |
| 11    | 1.0627                          | 31    | 1.1962                          | 51    | 1.3573                          |
| 12    | 1.0688                          | 32    | 1.2036                          | 52    | 1.3661                          |
| 13    | 1.0749                          | 33    | 1.2111                          | 53    | 1.3750                          |
| 14    | 1.0811                          | 34    | 1.2186                          | 54    | 1.3840                          |
| 15    | 1.0874                          | 35    | 1.2262                          | 55    | 1.3931                          |
| 16    | 1.0937                          | 36    | 1.2338                          | 56    | 1.4022                          |
| 17    | 1.1001                          | 37    | 1.2415                          | 57    | 1.4114                          |
| 18    | 1.1065                          | 38    | 1.2493                          | 58    | 1.4207                          |
| 19    | 1.1130                          | 39    | 1.2572                          | 59    | 1.4301                          |
| 20    | 1.1196                          | 40    | 1.2651                          | 60    | 1.4395                          |

## Specific Gravity of Potash Alum Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, 27, 307.)

$g\%$  = gms. of  $K_2SO_4Al_2(SO_4)_3 \cdot 24H_2O$  in 100 gms. of solution.

| $g\%$ | $S_{17.5^\circ C.}^{17.5^\circ C.}$ | $g\%$ | $S_{17.5^\circ C.}^{17.5^\circ C.}$ | $g\%$ | $S_{17.5^\circ C.}^{17.5^\circ C.}$ |
|-------|-------------------------------------|-------|-------------------------------------|-------|-------------------------------------|
| 1     | 1.0049                              | 6     | 1.0310                              | 10    | 1.0523                              |
| 2     | 100                                 | 7     | 362                                 | 11    | 578                                 |
| 3     | 152                                 | 8     | 415                                 | 12    | 635                                 |
| 4     | 205                                 | 9     | 469                                 | 13    | 690                                 |
| 5     | 258                                 |       |                                     |       |                                     |

## Specific Gravity of Potassium Acetate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 313.)

$g\%$  = gms. of  $\text{CH}_3\text{COOK}$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.0049  | 21    | 1.1058  | 41    | 1.2162  |
| 2     | 098   | 22    | 111   | 42    | 219   |
| 3     | 147   | 23    | 164   | 43    | 276   |
| 4     | 196   | 24    | 217   | 44    | 333   |
| 5     | 245   | 25    | 270   | 45    | 390   |
| 6     | 294   | 26    | 325   | 46    | 449   |
| 7     | 343   | 27    | 380   | 47    | 508   |
| 8     | 392   | 28    | 435   | 48    | 567   |
| 9     | 441   | 29    | 490   | 49    | 626   |
| 10    | 490   | 30    | 545   | 50    | 685   |
| 11    | 540   | 31    | 600   | 51    | 744   |
| 12    | 590   | 32    | 655   | 52    | 803   |
| 13    | 640   | 33    | 710   | 53    | 862   |
| 14    | 690   | 34    | 765   | 54    | 921   |
| 15    | 740   | 35    | 820   | 55    | 980   |
| 16    | 793   | 36    | 877   | 56    | 1.3041  |
| 17    | 846   | 37    | 934   | 57    | 102   |
| 18    | 899   | 38    | 991   | 58    | 163   |
| 19    | 952   | 39    | 1.2048  | 59    | 224   |
| 20    | 1.1005  | 40    | 105   | 60    | 285   |

## Specific Gravity of Potassium Bisulphide Solutions.

(Bock, *Wied. Ann.*, 1887, **30**, 631.)

$g\%$  = gms. of  $\text{KHS}$  in 100 gms. of solution

| $g\%$ | $S_{\frac{18^\circ\text{C.}}{4^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{18^\circ\text{C.}}{4^\circ\text{C.}}}$ |
|-------|--|-------|--|
| 4.09  | 1.0232   | 33.43 | 1.2124   |
| 7.86  | 1.0456   | 39.22 | 1.2428   |
| 15.08 | 1.0889   | 51.22 | 1.3226   |

## Specific Gravity of Potassium Bromate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$  = gms. of  $\text{KBrO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ |
|-------|---|-------|---|
| 1     | 1.009   | 6     | 1.046   |
| 2     | 16  | 7     | 54  |
| 3     | 24  | 8     | 62  |
| 4     | 31  | 9     | 70  |
| 5     | 39  | 10    | 79  |

## Specific Gravity of Potassium Carbonate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 279.)

$g\%$  = gms. of  $\text{K}_2\text{CO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{15^\circ\text{C.}}{15^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.00914   | 19    | 1.18265   | 36    | 1.37082   |
| 2     | 1829  | 20    | 9286  | 37    | 8279  |
| 3     | 2743  | 21    | 1.20344   | 38    | 9476  |
| 4     | 3658  | 22    | 1402  | 39    | 1.40673   |
| 5     | 4572  | 23    | 2459  | 40    | 1870  |
| 6     | 5513  | 24    | 3517  | 41    | 3104  |
| 7     | 6454  | 25    | 4575  | 42    | 4338  |
| 8     | 7396  | 26    | 5681  | 43    | 4573  |
| 9     | 8337  | 27    | 6787  | 44    | 6807  |
| 10    | 9278  | 28    | 7893  | 45    | 8041  |
| 11    | 1.10258   | 29    | 8999  | 46    | 9314  |
| 12    | 1238  | 30    | 1.30105   | 47    | 1.50588   |
| 13    | 2219  | 31    | 1261  | 48    | 1861  |
| 14    | 3199  | 32    | 2417  | 49    | 3135  |
| 15    | 4179  | 33    | 3573  | 50    | 4408  |
| 16    | 5200  | 34    | 4729  | 51    | 5728  |
| 17    | 6222  | 35    | 5885  | 52    | 7048  |
| 18    | 7243  |       |   |       |   |



## Density of Potassium Bromide Solutions.

(J. Y. Buchanan, *Trans. Roy. Soc. Edin.*, 1912, **49**, 223 & 224.)

$g\%$  = gms. of KBr in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|-------|--|-------|--|-------|--|
| 0.74  | 1.0036   | 5.62  | 1.0396   | 26.32 | 1.2200   |
| 1.47  | 1.0089   | 10.64 | 1.0790   | 32.27 | 1.2832   |
| 2.89  | 1.0192   | 19.24 | 1.1526   | 37.32 | 1.3403   |

## Specific Gravity of Potassium Chlorate Solutions

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$  = gms. of  $\text{KClO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{19.5^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{19.5^{\circ}\text{C.}}}$ |
|-------|---|-------|---|
| 1     | 1.007   | 6     | 1.039   |
| 2     | 1.014   | 7     | 1.045   |
| 3     | 1.020   | 8     | 1.052   |
| 4     | 1.026   | 9     | 1.059   |
| 5     | 1.033   | 10    | 1.066   |

## Density of Potassium Chloride Solutions.

(J. Y. Buchanan, *Trans. Roy. Soc. Edin.*, 1912, **49**, 222 & 224.)

$g\%$  = gms. of KCl in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|-------|--|-------|--|
| 0.92  | 1.0043   | 12.98 | 1.0835   |
| 1.83  | 1.0100   | 18.29 | 1.1204   |
| 3.60  | 1.0213   | 22.98 | 1.1543   |
| 6.94  | 1.0432   |       |  |

## Specific Gravity of Potassium Chromate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 288.)

$g\%$  = gms. of  $K_2CrO_4$  in 100 gms. of solution.

| $g\%$ | $S_{19.5^\circ C.}^{19.5^\circ C.}$ | $g\%$ | $S_{19.5^\circ C.}^{19.5^\circ C.}$ | $g\%$ | $S_{19.5^\circ C.}^{19.5^\circ C.}$ | $g\%$ | $S_{19.5^\circ C.}^{19.5^\circ C.}$ |
|-------|-------------------------------------|-------|-------------------------------------|-------|-------------------------------------|-------|-------------------------------------|
| 1     | 1.0080                              | 11    | 1.0925                              | 21    | 1.1864                              | 31    | 1.2921                              |
| 2     | 161                                 | 12    | 1.1014                              | 22    | 964                                 | 32    | 1.3035                              |
| 3     | 243                                 | 13    | 104                                 | 23    | 1.2066                              | 33    | 151                                 |
| 4     | 325                                 | 14    | 195                                 | 24    | 169                                 | 34    | 268                                 |
| 5     | 408                                 | 15    | 287                                 | 25    | 274                                 | 35    | 386                                 |
| 6     | 492                                 | 16    | 380                                 | 26    | 379                                 | 36    | 505                                 |
| 7     | 576                                 | 17    | 474                                 | 27    | 485                                 | 37    | 625                                 |
| 8     | 663                                 | 18    | 570                                 | 28    | 592                                 | 38    | 746                                 |
| 9     | 750                                 | 19    | 667                                 | 29    | 700                                 | 39    | 868                                 |
| 10    | 837                                 | 20    | 765                                 | 30    | 808                                 | 40    | 991                                 |

## Specific Gravity of Potassium Chrome Alum Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 497.)

$g\%$  = gms. of  $K_2SO_4Cr_2(SO_4)_3 \cdot 24H_2O$  in 100 gms. of solution.

Violet modification.

| $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ | $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ |
|-------|---------------------------------|-------|---------------------------------|
| 5     | 1.02725                         | 15    | 1.08350                         |
| 10    | 1.05500                         |       |                                 |

Green modification.

| $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ | $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ |
|-------|---------------------------------|-------|---------------------------------|
| 10    | 1.050                           | 60    | 1.371                           |
| 20    | 1.103                           | 70    | 1.453                           |
| 30    | 1.161                           | 80    | 1.541                           |
| 40    | 1.225                           | 90    | 1.635                           |
| 50    | 1.295                           |       |                                 |

### Sp. Gr. of Potassium Dichromate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 288.)

$g\%$  = gms. of  $K_2Cr_2O_7$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^{\circ}C.}{19.5^{\circ}C.}}$ | $g\%$ | $S_{\frac{19.5^{\circ}C.}{19.5^{\circ}C.}}$ | $g\%$ | $S_{\frac{19.5^{\circ}C.}{19.5^{\circ}C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.007                                       | 6     | 1.043                                       | 11    | 1.080                                       |
| 2     | 15  | 7     | 50  | 12    | 87  |
| 3     | 22  | 8     | 56  | 13    | 95  |
| 4     | 30  | 9     | 65  | 14    | 1.102                                       |
| 5     | 37  | 10    | 73  | 15    | 10  |

### Sp. Gr. of Potassium Ferricyanide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 290.)

$g\%$  = gms. of  $K_3Fe(CN)_6$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{13^{\circ}C.}{13^{\circ}C.}}$ | $g\%$ | $S_{\frac{13^{\circ}C.}{13^{\circ}C.}}$ | $g\%$ | $S_{\frac{13^{\circ}C.}{13^{\circ}C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.0051                                  | 11    | 1.0595                                  | 21    | 1.1202                                  |
| 2     | 103                                     | 12    | 653                                     | 22    | 266                                     |
| 3     | 155                                     | 13    | 712                                     | 23    | 331                                     |
| 4     | 208                                     | 14    | 771                                     | 24    | 396                                     |
| 5     | 261                                     | 15    | 831                                     | 25    | 462                                     |
| 6     | 315                                     | 16    | 891                                     | 26    | 529                                     |
| 7     | 370                                     | 17    | 952                                     | 27    | 596                                     |
| 8     | 426                                     | 18    | 1.1014                                  | 28    | 664                                     |
| 9     | 482                                     | 19    | 076                                     | 29    | 732                                     |
| 10    | 538                                     | 20    | 139                                     | 30    | 802                                     |

### Sp. Gr. of Potassium Ferrocyanide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 290.)

$g\%$  = gms. of  $K_4Fe(CN)_6 \cdot 3H_2O$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^{\circ}C.}{15^{\circ}C.}}$ | $g\%$ | $S_{\frac{15^{\circ}C.}{15^{\circ}C.}}$ | $g\%$ | $S_{\frac{15^{\circ}C.}{15^{\circ}C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.0058                                  | 8     | 1.0479                                  | 15    | 1.0932                                  |
| 2     | 1.0116                                  | 9     | 1.0542                                  | 16    | 1.0999                                  |
| 3     | 1.0175                                  | 10    | 1.0605                                  | 17    | 1.1067                                  |
| 4     | 1.0234                                  | 11    | 1.0669                                  | 18    | 1.1136                                  |
| 5     | 1.0295                                  | 12    | 1.0734                                  | 19    | 1.1205                                  |
| 6     | 1.0356                                  | 13    | 1.0800                                  | 20    | 1.1275                                  |
| 7     | 1.0417                                  | 14    | 1.0866                                  |       |   |

# Density of Potassium Hydroxide Solutions.

(Pickering, 1893.)

$g\%$  = gms. of KOH in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|-------|--|-------|--|-------|--|
| 1     | 1.0083   | 19    | 1.1786   | 36    | 1.3549   |
| 2     | 175  | 20    | 884  | 37    | 659  |
| 3     | 267  | 21    | 984  | 38    | 769  |
| 4     | 359  | 22    | 1.2083   | 39    | 879  |
| 5     | 452  | 23    | 184  | 40    | 991  |
| 6     | 544  | 24    | 285  | 41    | 1.4103   |
| 7     | 637  | 25    | 387  | 42    | 215  |
| 8     | 730  | 26    | 489  | 43    | 329  |
| 9     | 824  | 27    | 592  | 44    | 443  |
| 10    | 918  | 28    | 695  | 45    | 558  |
| 11    | 1.1013   | 29    | 800  | 46    | 673  |
| 12    | 108  | 30    | 905  | 47    | 790  |
| 13    | 203  | 31    | 1.3010   | 48    | 907  |
| 14    | 299  | 32    | 117  | 49    | 1.5025   |
| 15    | 396  | 33    | 224  | 50    | 143  |
| 16    | 493  | 34    | 331  | 51    | 262  |
| 17    | 590  | 35    | 440  | 52    | 382  |
| 18    | 688  |       |  |       |  |

# Specific Gravity of Potassium Iodate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 290.)

$g\%$  = gms. of  $\text{KIO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{19.5^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{19.5^{\circ}\text{C.}}}$ |
|-------|---|-------|---|
| 1     | 1.010   | 6     | 1.052   |
| 2     | 19  | 7     | 61  |
| 3     | 27  | 8     | 71  |
| 4     | 35  | 9     | 80  |
| 5     | 44  | 10    | 90  |

## Density of Potassium Iodide Solutions.

(J. Y. Buchanan, *Trans. Roy. Soc. Edin.*, 1912, **49**, 223/4.)  
 $g\%$  = gms. of KI in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|-------|--|-------|--|
| 1.03  | 1.0059   | 33.26 | 1.3097   |
| 2.03  | 1.0135   | 39.92 | 1.3959   |
| 3.99  | 1.0282   | 45.37 | 1.4766   |
| 7.67  | 1.0572   | 49.91 | 1.5458   |
| 14.24 | 1.1128   | 53.76 | 1.6115   |
| 24.94 | 1.2157   | 57.06 | 1.6722   |

## Specific Gravity of Potassium Iron Alum Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 496.)

$g\%$  = gms. of  $\text{K}_2\text{SO}_4\text{Fe}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{15^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{15^{\circ}\text{C.}}}$ |
|-------|---|-------|---|
| 5     | 1.0250  | 25    | 1.1340  |
| 10    | 1.0507  | 30    | 1.1645  |
| 15    | 1.0773  | 35    | 1.1967  |
| 20    | 1.1050  |       |   |

## Specific Gravity of Potassium Nitrate Solutions

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)

$g\%$  = gms. of  $\text{KNO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{15^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{15^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{15^{\circ}\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.00641   | 9     | 1.05861   | 17    | 1.11426   |
| 2     | 1283  | 10    | 6524  | 18    | 2150  |
| 3     | 1924  | 11    | 7215  | 19    | 2875  |
| 4     | 2566  | 12    | 7905  | 20    | 3599  |
| 5     | 3207  | 13    | 8596  | 21    | 4361  |
| 6     | 3870  | 14    | 9286  |       |   |
| 7     | 4534  | 15    | 9977  |       |   |
| 8     | 5197  | 16    | 1.10701   |       |   |

# Specific Gravity of Potassium Oxalate Solutions

(Gerlach, *Z. anal. Chem.*, 1888, 27, 315.)

$g\%$  = gms. of  $K_2C_2O_4 \cdot H_2O$  in 100 gms. of solution.

| $g\%$ | $S_{17.5^\circ C.}^{17.5^\circ C.}$ | $g\%$ | $S_{17.5^\circ C.}^{17.5^\circ C.}$ | $g\%$ | $S_{17.5^\circ C.}^{17.5^\circ C.}$ |
|-------|-------------------------------------|-------|-------------------------------------|-------|-------------------------------------|
| 1     | 1.0067                              | 10    | 1.0656                              | 19    | 1.1241                              |
| 2     | 134                                 | 11    | 720                                 | 20    | 306                                 |
| 3     | 201                                 | 12    | 784                                 | 21    | 372                                 |
| 4     | 268                                 | 13    | 848                                 | 22    | 438                                 |
| 5     | 337                                 | 14    | 912                                 | 23    | 504                                 |
| 6     | 401                                 | 15    | 977                                 | 24    | 570                                 |
| 7     | 465                                 | 16    | 1.1043                              | 25    | 638                                 |
| 8     | 529                                 | 17    | 109                                 |       |                                     |
| 9     | 593                                 | 18    | 175                                 |       |                                     |

## Specific Gravity $S_{17.5^\circ C.}^{17.5^\circ C.}$ of Solutions of the Acid

### Potassium Oxalates.

(Gerlach, *Z. anal. Chem.*, 1888, 27, 315.)

$g\%$  = gms. of salt of formulæ given in 100 gms. of solution.

| $g\%$                        | 1      | 2      | 3      | 4      | 5      |
|------------------------------|--------|--------|--------|--------|--------|
| $KHC_2O_4 + H_2O$            | 1.0055 | 1.0110 | 1.0164 | 1.0218 | 1.0271 |
| $KHC_2O_4, H_2C_2O_4 + H_2O$ | 1.0047 | 1.0093 |        |        |        |

## Specific Gravity of Potassium Sulphate Solutions

(Gerlach, *Z. anal. Chem.*, 1869, 8, 286.)

$g\%$  = gms. of  $K_2SO_4$  in 100 gms. of solution.

| $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ | $g\%$ | $S_{15^\circ C.}^{15^\circ C.}$ |
|-------|---------------------------------|-------|---------------------------------|
| 1     | 1.00820                         | 5     | 1.04105                         |
| 2     | 1635                            | 6     | 4947                            |
| 3     | 2450                            | 7     | 5790                            |
| 4     | 3277                            | 8     | 6644                            |
|       |                                 | 9     | 7499                            |

## Density of Potassium Sulphide Solutions.

(Bock, *Wied. Ann.*, 1887, **30**, 631.)

$g\%$  = gms. of  $K_2S$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{18^\circ C.}{4^\circ C.}}$ | $g\%$ | $S_{\frac{18^\circ C.}{4^\circ C.}}$ | $g\%$ | $S_{\frac{18^\circ C.}{4^\circ C.}}$ |
|-------|--------------------------------------|-------|--------------------------------------|-------|--------------------------------------|
| 3.18  | 1.0265                               | 15.06 | 1.1285                               | 29.97 | 1.2672                               |
| 4.98  | 1.0405                               | 19.96 | 1.1738                               | 38.08 | 1.3501                               |
| 9.93  | 1.0829                               | 24.64 | 1.2186                               | 47.26 | 1.4596                               |

## Specific Gravity of Potassium Tartrate Solutions

(Gerlach, *Z. anal. Chem.*, 1887, **26**, 505.)

$g\%$  = gms. of  $C_4H_4O_6K_2$  in 100 gms. of solution.

| $g\%$  | $S_{\frac{19.5^\circ C.}{19.5^\circ C.}}$ | $g\%$  | $S_{\frac{19.5^\circ C.}{19.5^\circ C.}}$ |
|--------|---|--------|---|
| 17.376 | 1.1198                                    | 52.071 | 1.4194                                    |
| 31.394 | 1.2299                                    | 60.333 | 1.5051                                    |
| 43.423 | 1.3355                                    |        |   |

## Specific Gravity of Rochelle Salt Solutions.

(Gerlach, *Z. anal. Chem.*, 1887, **26**, 505.)

$g\%$  = gms. of  $C_4H_4O_6NaK4H_2O$  in 100 gms. of solution.

$G\%$  = gms. of  $C_4H_4O_6NaK$  in 100 gms. of solution.

| $g\%$ | $G\%$  | $S_{\frac{17.5^\circ C.}{17.5^\circ C.}}$ | $g\%$ | $G\%$  | $S_{\frac{17.5^\circ C.}{17.5^\circ C.}}$ |
|-------|--------|---|-------|--------|---|
| 10    | 7.448  | 1.0510                                    | 40    | 29.729 | 1.2230                                    |
| 20    | 14.896 | 1.1050                                    | 50    | 37.240 | 1.2890                                    |
| 30    | 22.344 | 1.1620                                    |       |        |   |

## Density of Silver Nitrate Solutions.

(Landolt and Börnstein, from Kohlrausch, *Wied. Ann.*, 1879, **6**, 1-145.)

$g\%$  = gms. of  $AgNO_3$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{18^\circ C.}{4^\circ C.}}$ | $g\%$ | $S_{\frac{18^\circ C.}{4^\circ C.}}$ | $g\%$ | $S_{\frac{18^\circ C.}{4^\circ C.}}$ | $g\%$ | $S_{\frac{18^\circ C.}{4^\circ C.}}$ |
|-------|--------------------------------------|-------|--------------------------------------|-------|--------------------------------------|-------|--------------------------------------|
| 5     | 1.0422                               | 20    | 1.1958                               | 35    | 1.3945                               | 50    | 1.6745                               |
| 10    | 1.0893                               | 25    | 1.2555                               | 40    | 1.4773                               | 55    | 1.7895                               |
| 15    | 1.1404                               | 30    | 1.3213                               | 45    | 1.5705                               | 60    | 1.9158                               |

## Specific Gravity of Sodium Acetate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 313.)

$g\%$  = gms. of  $\text{CH}_3\text{COONa}$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{17.5^\circ\text{C.}}{17.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.005   | 11    | 1.057   | 21    | 1.113   |
| 2     | 10  | 12    | 63  | 22    | 19  |
| 3     | 16  | 13    | 68  | 23    | 24  |
| 4     | 21  | 14    | 74  | 24    | 30  |
| 5     | 26  | 15    | 79  | 25    | 36  |
| 6     | 31  | 16    | 85  | 26    | 42  |
| 7     | 36  | 17    | 90  | 27    | 48  |
| 8     | 42  | 18    | 96  | 28    | 54  |
| 9     | 47  | 19    | 1.101   | 29    | 60  |
| 10    | 52  | 20    | 07  | 30    | 66  |
|       |   |       |   | 31    | 72  |

## Specific Gravity of Sodium Arsenate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 296.)

$g\%$  = gms. of  $\text{Na}_3\text{AsO}_4 \cdot 12\text{H}_2\text{O}$  in 100 gms. of solution.  
 $G\%$  = gms. of  $\text{Na}_3\text{AsO}_4$  in 100 gms. of solution.

| $g\%$ | $G\%$ | $S_{\frac{17^\circ\text{C}}{17^\circ\text{C}}}$ | $g\%$ | $G\%$ | $S_{\frac{17^\circ\text{C}}{17^\circ\text{C}}}$ |
|-------|-------|---|-------|-------|---|
| 1     | 0.49  | 1.0053  | 12    | 5.89  | 1.0659  |
| 2     | 0.98  | 107   | 13    | 6.38  | 716   |
| 3     | 1.47  | 161   | 14    | 6.87  | 773   |
| 4     | 1.96  | 215   | 15    | 7.36  | 830   |
| 5     | 2.45  | 270   | 16    | 7.85  | 887   |
| 6     | 2.94  | 325   | 17    | 8.34  | 945   |
| 7     | 3.43  | 380   | 18    | 8.83  | 1.1003  |
| 8     | 3.92  | 435   | 19    | 9.32  | 061   |
| 9     | 4.41  | 491   | 20    | 9.81  | 120   |
| 10    | 4.91  | 547   | 21    | 10.30 | 179   |
| 11    | 5.40  | 603   | 22    | 10.79 | 238   |



## Specific Gravity of Acid Sodium Arsenate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 286.)

$g\%$  = gms. of  $\text{Na}_2\text{HAsO}_4 \cdot 12\text{H}_2\text{O}$  in 100 gms. of solution.  
 $G\%$  = gms. of  $\text{Na}_2\text{HAsO}_4$  in 100 gms. of solution.

| $g\%$ | $G\%$ | $S_{\frac{14^\circ\text{C.}}{14^\circ\text{C.}}}$ | $g\%$ | $G\%$ | $S_{\frac{14^\circ\text{C.}}{14^\circ\text{C.}}}$ |
|-------|-------|---|-------|-------|---|
| 1     | 0.46  | 1.0042  | 21    | 9.71  | 1.0953  |
| 2     | 0.93  | 084   | 22    | 10.18 | 1.1002  |
| 3     | 1.39  | 126   | 23    | 10.64 | 052   |
| 4     | 1.85  | 168   | 24    | 11.10 | 102   |
| 5     | 2.31  | 212   | 25    | 11.57 | 153   |
| 6     | 2.78  | 256   | 26    | 12.03 | 204   |
| 7     | 3.24  | 300   | 27    | 12.49 | 255   |
| 8     | 3.70  | 344   | 28    | 12.95 | 306   |
| 9     | 4.16  | 389   | 29    | 13.42 | 358   |
| 10    | 4.63  | 434   | 30    | 13.88 | 410   |
| 11    | 5.09  | 479   | 31    | 14.34 | 463   |
| 12    | 5.55  | 525   | 32    | 14.80 | 516   |
| 13    | 6.01  | 571   | 33    | 15.27 | 569   |
| 14    | 6.48  | 618   | 34    | 15.73 | 623   |
| 15    | 6.94  | 665   | 35    | 16.19 | 677   |
| 16    | 7.40  | 712   | 36    | 16.65 | 731   |
| 17    | 7.86  | 759   | 37    | 17.12 | 786   |
| 18    | 8.33  | 807   | 38    | 17.58 | 818   |
| 19    | 8.78  | 855   | 39    | 18.04 | 896   |
| 20    | 9.25  | 904   | 40    | 18.50 | 952   |

## Specific Gravity of Sodium Bromate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 290.)

$g\%$  = gms. of  $\text{NaBrO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ |
|-------|---|-------|---|
| 2     | 1.016   | 18    | 1.156   |
| 4     | 33  | 20    | 78  |
| 6     | 49  | 22    | 99  |
| 8     | 66  | 24    | 1.220   |
| 10    | 83  | 26    | 42  |
| 12    | 1.101   | 28    | 65  |
| 14    | 20  | 30    | 89  |
| 16    | 37  |       |   |

### Density of Sodium Bromide Solutions.

(Baxter and Wallace, *J. Am. Chem. Soc.*, 1916, **38**, 70.)

G=gms. of NaBr in 1 litre of solution.

| G.     | $S \frac{0^{\circ}\text{C.}}{4^{\circ}\text{C.}}$ | G.     | $S \frac{25^{\circ}\text{C.}}{4^{\circ}\text{C.}}$ |
|--------|---|--------|--|
| 563.89 | 1.42228   | 563.49 | 1.40972  |
| 281.17 | 1.21601   | 280.95 | 1.20608  |
| 112.67 | 1.08854   | 112.58 | 1.08200  |
| 56.03  | 1.04444   | 56.00  | 1.03962  |
| 27.88  | 1.02222   | 27.86  | 1.01833  |

### Specific Gravity of Sodium Carbonate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 279.)

$g\%$  = gms. of  $\text{Na}_2\text{CO}_3$  in 100 gms. of solution.

| $g\%$ | $S \frac{15^{\circ}\text{C.}}{15^{\circ}\text{C.}}$ | $g\%$ | $S \frac{15^{\circ}\text{C.}}{15^{\circ}\text{C.}}$ | $g\%$ | $S \frac{15^{\circ}\text{C.}}{15^{\circ}\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.01050   | 6     | 1.06309   | 11    | 1.11655   |
| 2     | 2101  | 7     | 7369  | 12    | 2740  |
| 3     | 3151  | 8     | 8430  | 13    | 3845  |
| 4     | 4201  | 9     | 9500  | 14    | 4950  |
| 5     | 5255  | 10    | 1.10571   |       |   |

### Change in Specific Gravity of Sodium Carbonate Solutions with Temperature.

(Lunge and Keane, "Tech. Methods of Chem. Anal., 1908, Vol. I, p. 449.)

C=fall in specific gravity for  $1^{\circ}\text{C.}$  rise at room temperature.

| $S \frac{15^{\circ}\text{C.}}{15^{\circ}\text{C.}}$ | C.     |
|---|--------|
| 1.01 to 1.05  | 0.0002 |
| 1.06 „ 1.07   | 0.0003 |
| 1.08 „ 1.11   | 0.0004 |
| 1.12 „ 1.17   | 0.0004 |
| 1.18 „ 1.20   | 0.0004 |
| 1.21 „ 1.24   | 0.0005 |

# Specific Gravity of Sodium Chlorate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$  = gms. of  $\text{NaClO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{19.5^\circ\text{C.}}^{19.5^\circ\text{C.}}$ | $g\%$ | $S_{19.5^\circ\text{C.}}^{19.5^\circ\text{C.}}$ | $g\%$ | $S_{19.5^\circ\text{C.}}^{19.5^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.007   | 15    | 1.108   | 29    | 1.225   |
| 2     | 15  | 16    | 16  | 30    | 35  |
| 3     | 21  | 17    | 24  | 31    | 44  |
| 4     | 28  | 18    | 31  | 32    | 52  |
| 5     | 35  | 19    | 40  | 33    | 62  |
| 6     | 41  | 20    | 47  | 34    | 72  |
| 7     | 48  | 21    | 55  | 35    | 82  |
| 8     | 55  | 22    | 65  | 36    | 91  |
| 9     | 63  | 23    | 74  | 37    | 1.301   |
| 10    | 70  | 24    | 81  | 38    | 11  |
| 11    | 78  | 25    | 90  | 39    | 21  |
| 12    | 85  | 26    | 1.200   | 40    | 31  |
| 13    | 94  | 27    | 08  |       |   |
| 14    | 1.100   | 28    | 16  |       |   |

# Specific Gravity of Sodium Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 281.)

$g\%$  = gms. of  $\text{NaCl}$  in 100 gms. of solution.

| $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.00725                                     | 10    | 1.07335                                     | 19    | 1.14315                                     |
| 2     | 1450  | 11    | 8097  | 20    | 5107  |
| 3     | 2174  | 12    | 8859  | 21    | 5931  |
| 4     | 2899  | 13    | 9622  | 22    | 6755  |
| 5     | 3624  | 14    | 1.10384                                     | 23    | 7580  |
| 6     | 4366  | 15    | 1146  | 24    | 8404  |
| 7     | 5108  | 16    | 1938  | 25    | 9228  |
| 8     | 5851  | 17    | 2730  | 26    | 1.20098                                     |
| 9     | 6593  | 18    | 3523  |       |   |

## Density of Sodium Hydroxide Solutions.

(Bousfield and Lowry, *Phil. Trans.*, 1905, A, **204**, 279.)

$g\%$  = gms. of NaOH in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|-------|--|-------|--|-------|--|
| 1     | 1.01065  | 18    | 1.19973  | 35    | 1.3830   |
| 2     | 2198   | 19    | 1.21079  | 36    | 933  |
| 3     | 3322   | 20    | 2183   | 37    | 1.4034   |
| 4     | 4441   | 21    | 3285   | 38    | 135  |
| 5     | 5554   | 22    | 439  | 39    | 235  |
| 6     | 6666   | 23    | 5485   | 40    | 334  |
| 7     | 7777   | 24    | 658  | 41    | 432  |
| 8     | 8887   | 25    | 768  | 42    | 529  |
| 9     | 9997   | 26    | 877  | 43    | 625  |
| 10    | 1.11107  | 27    | 986  | 44    | 720  |
| 11    | 2217   | 28    | 1.3094   | 45    | 815  |
| 12    | 3327   | 29    | 202  | 46    | 911  |
| 13    | 4436   | 30    | 309  | 47    | 1.5007   |
| 14    | 5545   | 31    | 415  | 48    | 102  |
| 15    | 6653   | 32    | 520  | 49    | 196  |
| 16    | 7761   | 33    | 624  | 50    | 290  |
| 17    | 8868   | 34    | 728  |       |  |

$\delta$  = fall in density per  $^{\circ}\text{C.}$  rise in temp. at room temperatures

| $g\%$  | $\delta$ | $g\%$    | $\delta$ |
|--------|----------|----------|----------|
| 1 to 2 | 0.0002   | 11 to 23 | 0.0005   |
| 3 „ 5  | 0.0003   | 24 „ 35  | 0.0006   |
| 6 „ 10 | 0.0004   | 36 „ 50  | 0.0007   |

## Specific Gravity of Sodium Iodate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$  = gms. of  $\text{NaIO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{19.5^{\circ}\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^{\circ}\text{C.}}{19.5^{\circ}\text{C.}}}$ |
|-------|---|-------|---|
| 1     | 1.010   | 6     | 1.054   |
| 2     | 19  | 7     | 65  |
| 3     | 28  | 8     | 75  |
| 4     | 36  | 9     | 85  |
| 5     | 44  | 10    | 95  |

## Density of Sodium Iodide Solutions.

(Baxter and Wallace, *J. Am. Chem. Soc.*, 1916, **38**, 70.)

G=gms. of NaI in 1 litre of solution.

| G.      | $S_{\frac{0^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | G.      | $S_{\frac{25^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|---------|---|---------|--|
| 1040.38 | 1.78425   | 1039.65 | 1.76970  |
| 518.75  | 1.39837   | 518.38  | 1.38569  |
| 207.86  | 1.16237   | 207.71  | 1.15413  |
| 103.38  | 1.08136   | 103.31  | 1.07550  |
| 51.45   | 1.04067   | 51.41   | 1.03624  |

## Density of Sodium Nitrate Solutions.

(J. Y. Buchanan, *Trans. Roy. Soc. Edin.*, 1912, **49**, 222 & 224.)

g%=gms. of  $\text{NaNO}_3$  in 100 gms. of solution.

| g%    | $S_{\frac{13.5^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | g%    | $S_{\frac{19.5^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ |
|-------|--|-------|--|
| 1.05  | 1.0055   | 25.37 | 1.1871   |
| 2.08  | 1.0125   | 29.82 | 1.2247   |
| 4.08  | 1.0261   | 33.77 | 1.2592   |
| 7.83  | 1.0525   | 37.30 | 1.2918   |
| 14.53 | 1.1012   | 40.48 | 1.3231   |
| 20.82 | 1.1459   | 43.34 | 1.3517   |

## Specific Gravity of Di-Sodium Phosphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)

g%=gms. of  $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$  in 100 gms. of solution.

G%=gms. of  $\text{Na}_2\text{HPO}_4$  in 100 gms. of solution.

| g% | G%   | $S_{\frac{19^{\circ}\text{C.}}{19^{\circ}\text{C.}}}$ | g% | G%   | $S_{\frac{19^{\circ}\text{C.}}{19^{\circ}\text{C.}}}$ |
|----|------|---|----|------|---|
| 1  | 0.40 | 1.0041  | 7  | 2.78 | 1.0292  |
| 2  | 0.79 | 083   | 8  | 3.18 | 332   |
| 3  | 1.19 | 125   | 9  | 3.57 | 375   |
| 4  | 1.59 | 166   | 10 | 3.97 | 418   |
| 5  | 1.98 | 208   | 11 | 4.37 | 460   |
| 6  | 2.38 | 250   | 12 | 4.76 | 503   |

## Specific Gravity of Tri-Sodium Phosphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)

$g\%$  = gms. of  $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$  in 100 gms. of solution.

$G\%$  = gms. of  $\text{Na}_3\text{PO}_4$  in 100 gms. of solution.

| $g\%$ | $G\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $G\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ |
|-------|-------|---|-------|-------|---|
| 2     | 0.86  | 1.0086                                      | 14    | 6.05  | 1.0633                                      |
| 6     | 2.59  | 263   | 18    | 7.78  | 827   |
| 10    | 4.32  | 455   | 22    | 9.51  | 1.1025                                      |

## Specific Gravity of Sodium Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 287.)

$g\%$  = gms. of  $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$  in 100 gms. of solution.

$G\%$  = gms. of  $\text{Na}_2\text{SO}_4$  in 100 gms. of solution.

| $g\%$ | $G\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ | $g\%$ | $G\%$ | $S_{15^\circ\text{C.}}^{15^\circ\text{C.}}$ |
|-------|-------|---|-------|-------|---|
| 1     | 0.44  | 1.004                                       | 16    | 7.06  | 1.064                                       |
| 2     | 0.88  | 08  | 17    | 7.50  | 69  |
| 3     | 1.32  | 13  | 18    | 7.94  | 73  |
| 4     | 1.76  | 16  | 19    | 8.38  | 77  |
| 5     | 2.21  | 20  | 20    | 8.82  | 82  |
| 6     | 2.65  | 24  | 21    | 9.26  | 86  |
| 7     | 3.09  | 28  | 22    | 9.70  | 90  |
| 8     | 3.53  | 32  | 23    | 10.14 | 94  |
| 9     | 3.97  | 36  | 24    | 10.58 | 98  |
| 10    | 4.41  | 40  | 25    | 11.02 | 1.103                                       |
| 11    | 4.85  | 44  | 26    | 11.47 | 07  |
| 12    | 5.29  | 47  | 27    | 11.91 | 11  |
| 13    | 5.73  | 52  | 28    | 12.35 | 16  |
| 14    | 6.17  | 56  | 29    | 12.79 | 20  |
| 15    | 6.61  | 60  | 30    | 13.23 | 25  |

## Density of Sodium Sulphide Solutions.

(Bock, *Wied. Ann.*, 1867, **30**, 631.)

$g\%$  = gms. of  $\text{Na}_2\text{S}$  in 100 gms. of solution.

| $g\%$ | $S_{18^\circ\text{C.}}^{4^\circ\text{C.}}$ | $g\%$ | $S_{18^\circ\text{C.}}^{4^\circ\text{C.}}$ |
|-------|--|-------|--|
| 2.02  | 1.0212                                     | 14.02 | 1.1583                                     |
| 5.03  | 1.0557                                     | 16.12 | 1.1810                                     |
| 9.64  | 1.1102                                     | 18.15 | 1.2158                                     |

## Specific Gravity of Sodium Sulphite Solutions.

(Cheneveau, *Ann. de chim. phys.*, 1907, (8), 12, 145.)

$g\%$  = gms. of  $\text{Na}_2\text{SO}_3$  in 100 gms. of solution.

| $g\%$ | $S_{19^\circ\text{C.}}^{19^\circ\text{C.}}$ | $g\%$ | $S_{19^\circ\text{C.}}^{19^\circ\text{C.}}$ | $g\%$ | $S_{19^\circ\text{C.}}^{19^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 2     | 1.0180                                      | 8     | 1.0747                                      | 14    | 1.1348                                      |
| 4     | .0365                                       | 10    | .0944                                       | 16    | .1553                                       |
| 6     | .0554                                       | 12    | .1145                                       |       |   |

## Specific Gravity of Sodium Thiosulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 288.)

$g\%$  = gms. of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$  in 100 gms. of solution.

$G\%$  = gms. of  $\text{Na}_2\text{S}_2\text{O}_3$  in 100 gms. of solution.

| $g\%$ | $G\%$ | $S_{19^\circ\text{C.}}^{19^\circ\text{C.}}$ | $g\%$ | $G\%$ | $S_{19^\circ\text{C.}}^{19^\circ\text{C.}}$ |
|-------|-------|---|-------|-------|---|
| 1     | 0.64  | 1.0052                                      | 26    | 16.56 | 1.1440                                      |
| 2     | 1.27  | 105   | 27    | 17.20 | 499   |
| 3     | 1.91  | 158   | 28    | 17.84 | 558   |
| 4     | 2.58  | 211   | 29    | 18.47 | 617   |
| 5     | 3.18  | 264   | 30    | 19.11 | 676   |
| 6     | 3.82  | 317   | 31    | 19.75 | 738   |
| 7     | 4.46  | 370   | 32    | 20.39 | 800   |
| 8     | 5.10  | 423   | 33    | 21.02 | 862   |
| 9     | 5.73  | 476   | 34    | 21.66 | 924   |
| 10    | 6.37  | 529   | 35    | 22.30 | 986   |
| 11    | 7.01  | 584   | 36    | 22.93 | 1.2048                                      |
| 12    | 7.64  | 639   | 37    | 23.57 | 110   |
| 13    | 8.28  | 695   | 38    | 24.21 | 172   |
| 14    | 8.92  | 751   | 39    | 24.85 | 234   |
| 15    | 9.56  | 807   | 40    | 25.48 | 297   |
| 16    | 10.19 | 863   | 41    | 26.12 | 362   |
| 17    | 10.83 | 919   | 42    | 26.76 | 427   |
| 18    | 11.47 | 975   | 43    | 27.39 | 492   |
| 19    | 12.10 | 1.1031                                      | 44    | 28.03 | 558   |
| 20    | 12.74 | 087   | 45    | 28.67 | 624   |
| 21    | 13.38 | 145   | 46    | 29.31 | 690   |
| 22    | 14.02 | 204   | 47    | 29.94 | 756   |
| 23    | 14.65 | 263   | 48    | 30.58 | 822   |
| 24    | 15.29 | 322   | 49    | 31.22 | 888   |
| 25    | 15.93 | 381   | 50    | 31.85 | 954   |

## Density of Sodium Tartrate Solutions.

(Pribram and Glücksman, *Wien. Ber.*, 1898.)

$g\%$  = gms. of  $\text{Na}_2\text{C}_4\text{H}_4\text{O}_6$  in 100 gms. of solution.

| $g\%$  | $S_{\frac{20^\circ\text{C.}}{4^\circ\text{C.}}}$ | $g\%$  | $S_{\frac{20^\circ\text{C.}}{4^\circ\text{C.}}}$ |
|--------|--|--------|--|
| 0.6059 | 1.00248  | 11.387 | 1.08056  |
| 2.4502 | 1555   | 15.237 | 1.10973  |
| 4.9563 | 3341   | 18.255 | 3381   |
| 6.7866 | 4671   | 22.608 | 6846   |
| 8.5866 | 5987   | 28.321 | 1.21559  |

## Specific Gravity of Sodium Tungstate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, 27, 308.)

$g\%$  = gms. of  $\text{Na}_2\text{WO}_4\cdot 2\text{H}_2\text{O}$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{24.5^\circ\text{C.}}{24.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{24.5^\circ\text{C.}}{24.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{24.5^\circ\text{C.}}{24.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.004   | 16    | 1.130   | 31    | 1.289   |
| 2     | 12  | 17    | 39  | 32    | 1.306   |
| 3     | 21  | 18    | 47  | 33    | 21  |
| 4     | 29  | 19    | 56  | 34    | 35  |
| 5     | 36  | 20    | 66  | 35    | 49  |
| 6     | 45  | 21    | 76  | 36    | 64  |
| 7     | 52  | 22    | 85  | 37    | 81  |
| 8     | 59  | 23    | 95  | 38    | 97  |
| 9     | 68  | 24    | 1.204   | 39    | 1.414   |
| 10    | 75  | 25    | 15  | 40    | 30  |
| 11    | 84  | 26    | 27  | 41    | 45  |
| 12    | 92  | 27    | 39  | 42    | 60  |
| 13    | 1.101   | 28    | 50  | 43    | 76  |
| 14    | 10  | 29    | 62  | 44    | 92  |
| 15    | 19  | 30    | 74  |       |   |



# Specific Gravity of Sugar Solutions.

(Plato, *Wiss. Abhand. Kaiserlich. Norm-Aich. Komm.*, vol. ii, 1900.)

$g\%$  = gms. of pure cane sugar in 100 gms. of solution.

| $g\%$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 0     | 1.000000  | 34    | 1.149113  | 68    | 1.338439  |
| 1     | 3891  | 35    | 1.154074  | 69    | 1.344670  |
| 2     | 7809  | 36    | 9069  | 70    | 1.350940  |
| 3     | 1.011755  | 37    | 1.164099  | 71    | 7247  |
| 4     | 5728  | 38    | 9164  | 72    | 1.363593  |
| 5     | 9729  | 39    | 1.174267  | 73    | 9978  |
| 6     | 1.023758  | 40    | 9405  | 74    | 1.376399  |
| 7     | 7817  | 41    | 1.184581  | 75    | 1.382859  |
| 8     | 1.031903  | 42    | 9792  | 76    | 9358  |
| 9     | 6019  | 43    | 1.195040  | 77    | 1.395893  |
| 10    | 1.040163  | 44    | 1.200324  | 78    | 1.402466  |
| 11    | 4338  | 45    | 5646  | 79    | 9076  |
| 12    | 8543  | 46    | 1.211004  | 80    | 1.415724  |
| 13    | 1.052777  | 47    | 6400  | 81    | 1.422408  |
| 14    | 7043  | 48    | 1.221832  | 82    | 9130  |
| 15    | 1.061338  | 49    | 7302  | 83    | 1.435889  |
| 16    | 5664  | 50    | 1.232810  | 84    | 1.442685  |
| 17    | 1.070023  | 51    | 8355  | 85    | 9518  |
| 18    | 4412  | 52    | 1.243938  | 86    | 1.456386  |
| 19    | 8833  | 53    | 9558  | 87    | 1.463292  |
| 20    | 1.083285  | 54    | 1.255217  | 88    | 1.470233  |
| 21    | 7771  | 55    | 1.260913  | 89    | 7210  |
| 22    | 1.092288  | 56    | 6647  | 90    | 1.484223  |
| 23    | 6829  | 57    | 1.272420  | 91    | 1.491272  |
| 24    | 1.101422  | 58    | 8231  | 92    | 8356  |
| 25    | 6039  | 59    | 1.284079  | 93    | 1.505474  |
| 26    | 1.110689  | 60    | 9966  | 94    | 1.512627  |
| 27    | 5373  | 61    | 1.295891  | 95    | 9815  |
| 28    | 1.120089  | 62    | 1.301854  | 96    | 1.527037  |
| 29    | 4840  | 63    | 7856  | 97    | 1.534293  |
| 30    | 9625  | 64    | 1.313896  | 98    | 1.541582  |
| 31    | 1.134445  | 65    | 9974  | 99    | 8903  |
| 32    | 9300  | 66    | 1.326091  | 100   | 1.556259  |
| 33    | 1.144189  | 67    | 1.332246  |       |   |

## Change in Specific Gravity of Sugar Solutions with Temperature.

(Plato, *Ibid.*)

$g\%$  = gms. of pure cane sugar in 100 gms. of solution.  
 $\delta$  = fall in specific gravity relative to water at  $15^{\circ}\text{C}$ . for  $1^{\circ}\text{C}$ .  
 rise in temp. at room temperatures.

| $g\%$ | $\delta$ | $g\%$ | $\delta$ | $g\%$ | $\delta$ |
|-------|----------|-------|----------|-------|----------|
| 0     | 0.00015  | 24    | 0.00028  | 48    | 0.00042  |
| 1     | 16       | 25    | 29       | 49    | 42       |
| 2     | 16       | 26    | 29       | 50    | 43       |
| 3     | 17       | 27    | 30       | 51    | 43       |
| 4     | 17       | 28    | 31       | 52    | 44       |
| 5     | 18       | 29    | 31       | 53    | 44       |
| 6     | 18       | 30    | 32       | 54    | 45       |
| 7     | 19       | 31    | 32       | 55    | 45       |
| 8     | 19       | 32    | 33       | 56    | 46       |
| 9     | 20       | 33    | 34       | 57    | 46       |
| 10    | 20       | 34    | 34       | 58    | 46       |
| 11    | 21       | 35    | 35       | 59    | 47       |
| 12    | 21       | 36    | 35       | 60    | 47       |
| 13    | 22       | 37    | 36       | 61    | 48       |
| 14    | 22       | 38    | 36       | 62    | 48       |
| 15    | 23       | 39    | 37       | 63    | 49       |
| 16    | 24       | 40    | 37       | 64    | 49       |
| 17    | 24       | 41    | 38       | 65    | 49       |
| 18    | 25       | 42    | 38       | 66    | 50       |
| 19    | 25       | 43    | 39       | 67    | 50       |
| 20    | 26       | 44    | 39       | 68    | 51       |
| 21    | 27       | 45    | 40       | 69    | 51       |
| 22    | 27       | 46    | 41       | 70    | 51       |
| 23    | 28       | 47    | 41       |       |          |

# Density and Specific Gravity of Sulphuric Acid Solutions.

(J. Domke, *Wiss. Abh. der K. Normal-Eichungs-Kommission*, 1904, Vol. V.)

$g\%$  = gms. of pure  $H_2SO_4$  in 100 gms. of solution.

| $g\%$ | $S_{4^{\circ}C.}^{15^{\circ}C.}$ | $S_{15^{\circ}C.}^{15^{\circ}C.}$ | $g\%$ | $S_{4^{\circ}C.}^{15^{\circ}C.}$ | $S_{15^{\circ}C.}^{15^{\circ}C.}$ |
|-------|----------------------------------|-----------------------------------|-------|----------------------------------|-----------------------------------|
| 0     | 0.99913                          | 1.00000                           | 38    | 1.28915                          | 1.29027                           |
| 1     | 1.00611                          | 0698                              | 39    | 9781                             | 9894                              |
| 2     | 1293                             | 1381                              | 40    | 1.30654                          | 1.30767                           |
| 3     | 1967                             | 2055                              | 41    | 1534                             | 1648                              |
| 4     | 2639                             | 2728                              | 42    | 2422                             | 2537                              |
| 5     | 3316                             | 3406                              | 43    | 3319                             | 3435                              |
| 6     | 4002                             | 4092                              | 44    | 4226                             | 4342                              |
| 7     | 4695                             | 4786                              | 45    | 5144                             | 5261                              |
| 8     | 5395                             | 5486                              | 46    | 6073                             | 6191                              |
| 9     | 6100                             | 6192                              | 47    | 7013                             | 7132                              |
| 10    | 6810                             | 6903                              | 48    | 7964                             | 8084                              |
| 11    | 7526                             | 7619                              | 49    | 8926                             | 9047                              |
| 12    | 8248                             | 8342                              | 50    | 9900                             | 1.40021                           |
| 13    | 8976                             | 9071                              | 51    | 1.40885                          | 1007                              |
| 14    | 9710                             | 9805                              | 52    | 1882                             | 2005                              |
| 15    | 1.10450                          | 1.10546                           | 53    | 2890                             | 3014                              |
| 16    | 1196                             | 1292                              | 54    | 3909                             | 4034                              |
| 17    | 1948                             | 2045                              | 55    | 4939                             | 5065                              |
| 18    | 2705                             | 2803                              | 56    | 5980                             | 6107                              |
| 19    | 3468                             | 3566                              | 57    | 7031                             | 7159                              |
| 20    | 4236                             | 4335                              | 58    | 8092                             | 8221                              |
| 21    | 5009                             | 5109                              | 59    | 9163                             | 9292                              |
| 22    | 5788                             | 5888                              | 60    | 1.50244                          | 1.50374                           |
| 23    | 6572                             | 6673                              | 61    | 1334                             | 1465                              |
| 24    | 7362                             | 7464                              | 62    | 2432                             | 2564                              |
| 25    | 8157                             | 8260                              | 63    | 3539                             | 3672                              |
| 26    | 8957                             | 9060                              | 64    | 4654                             | 4788                              |
| 27    | 9761                             | 9865                              | 65    | 5777                             | 5912                              |
| 28    | 1.20570                          | 1.20675                           | 66    | 6908                             | 7044                              |
| 29    | 1384                             | 1489                              | 67    | 8047                             | 8184                              |
| 30    | 2202                             | 2308                              | 68    | 9194                             | 9332                              |
| 31    | 3024                             | 3131                              | 69    | 1.60349                          | 1.60488                           |
| 32    | 3850                             | 3957                              | 70    | 1511                             | 1651                              |
| 33    | 4681                             | 4789                              | 71    | 2680                             | 2821                              |
| 34    | 5517                             | 5626                              | 72    | 3855                             | 3997                              |
| 35    | 6358                             | 6468                              | 73    | 5035                             | 5176                              |
| 36    | 7204                             | 7314                              | 74    | 6218                             | 6362                              |
| 37    | 8056                             | 8167                              | 75    | 7402                             | 7547                              |

| $g\%$ | $S_{15^{\circ}\text{C.}}^{4^{\circ}\text{C.}}$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | $S_{15^{\circ}\text{C.}}^{4^{\circ}\text{C.}}$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ |
|-------|--|---|-------|--|---|
| 76    | 1.68585  | 1.68731   | 89    | 1.81407  | 1.81564   |
| 77    | 9764   | 9911  | 90    | 1977   | 2135  |
| 78    | 1.70935  | 1.71083   | 91    | 2484   | 2642  |
| 79    | 2094   | 2243  | 92    | 2929   | 3088  |
| 80    | 3236   | 3386  | 93    | 3312   | 3471  |
| 81    | 4355   | 4506  | 94    | 3631   | 3790  |
| 82    | 5443   | 5595  | 95    | 3880   | 4040  |
| 83    | 6489   | 6642  | 96    | 4057   | 4217  |
| 84    | 7482   | 7636  | 97    | 4145   | 4305  |
| 85    | 8412   | 8567  | 98    | 4115   | 4275  |
| 86    | 9272   | 9428  | 99    | 3933   | 4093  |
| 87    | 1.80058  | 1.80214   | 100   | 3570   | 1.83729   |
| 88    | 0769   | 0926  |       |  |   |

### Density and Specific Gravity of Concentrated Sulphuric Acid Solutions. (Domke, *loc. cit.*)

$g\%$  = gms. of  $\text{H}_2\text{SO}_4$  in 100 gms. of solution.

| $g\%$ | $S_{15^{\circ}\text{C.}}^{4^{\circ}\text{C.}}$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | $S_{15^{\circ}\text{C.}}^{4^{\circ}\text{C.}}$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ |
|-------|--|---|-------|--|---|
| 90.0  | 1.81977  | 1.82135   | 95.0  | 1.83880  | 1.84040   |
| .2    | 2083   | 2241  | .2    | 3921   | 4082  |
| .4    | 2187   | 2345  | .4    | 3960   | 4120  |
| .6    | 2289   | 2447  | .6    | 3996   | 4156  |
| .8    | 2388   | 2546  | .8    | 4029   | 4189  |
| 91.0  | 2484   | 2642  | 96.0  | 4057   | 4217  |
| .2    | 2578   | 2736  | .2    | 4081   | 4241  |
| .4    | 2669   | 2827  | .4    | 4102   | 4262  |
| .6    | 2758   | 2916  | .6    | 4121   | 4281  |
| .8    | 2845   | 3003  | .8    | 4136   | 4296  |
| 92.0  | 2929   | 3088  | 97.0  | 4145   | 4305  |
| .2    | 3011   | 3170  | .2    | 4148   | 4309  |
| .4    | 3090   | 3249  | .4    | 4148   | 4308  |
| .6    | 3166   | 3325  | .6    | 4143   | 4303  |
| .8    | 3240   | 3399  | .8    | 4132   | 4292  |
| 93.0  | 3312   | 3471  | 98.0  | 4115   | 4275  |
| .2    | 3381   | 3540  | .2    | 4092   | 4252  |
| .4    | 3448   | 3607  | .4    | 4063   | 4223  |
| .6    | 3512   | 3671  | .6    | 4026   | 4186  |
| .8    | 3573   | 3732  | .8    | 3983   | 4143  |
| 94.0  | 3631   | 3790  | 99.0  | 3933   | 4093  |
| .2    | 3687   | 3846  | .2    | 3879   | 4039  |
| .4    | 3740   | 3899  | .4    | 3815   | 3975  |
| .6    | 3790   | 3949  | .6    | 3742   | 3902  |
| .8    | 3837   | 3997  | .8    | 3660   | 3819  |
| 95.0  | 3880   | 4040  | 100.0 | 3570   | 3775  |

# Hydrometer Correction Table for Sulphuric Acid.

(Domke, *loc. cit.*)

$g\%$  = gms. of  $H_2SO_4$  in 100 gms. of solution (*approximately*).  
 $S$  = reading on hydrometer at  $t^\circ C$ . The hydrometer is sup-

posed to read  $S_{\frac{15^\circ C}{4^\circ C}}$  correctly in sulphuric acid solutions at  $15^\circ C$ .

The true density  $S_{\frac{15^\circ C}{4^\circ C}}$  of the acid is given by

$$S_{\frac{15^\circ C}{4^\circ C}} = S + C(t - 15).$$

The true strength of the acid may be obtained from the true density by reference to the preceding tables.

| $g\%$ | $S$ . | $C$ .   | $g\%$ | $S$ . | $C$ .   |
|-------|-------|---------|-------|-------|---------|
| 0     | 0.999 | 0.00013 | 27    | 1.198 | 0.00065 |
| 1     | 1.006 | 16      | 28    | 1.206 | 66      |
| 2     | 1.013 | 18      | 29    | 1.214 | 67      |
| 3     | 1.020 | 21      | 30    | 1.222 | 68      |
| 4     | 1.026 | 23      | 31    | 1.230 | 68      |
| 5     | 1.033 | 25      | 32    | 1.239 | 69      |
| 6     | 1.040 | 27      | 33    | 1.247 | 69      |
| 7     | 1.047 | 30      | 34    | 1.255 | 70      |
| 8     | 1.054 | 32      | 35    | 1.264 | 70      |
| 9     | 1.061 | 34      | 36    | 1.272 | 71      |
| 10    | 1.068 | 36      | 37    | 1.281 | 71      |
| 11    | 1.075 | 39      | 38    | 1.289 | 72      |
| 12    | 1.082 | 41      | 39    | 1.298 | 72      |
| 13    | 1.090 | 43      | 40    | 1.307 | 73      |
| 14    | 1.097 | 45      | 41    | 1.315 | 73      |
| 15    | 1.105 | 47      | 42    | 1.324 | 73      |
| 16    | 1.112 | 49      | 43    | 1.333 | 74      |
| 17    | 1.119 | 51      | 44    | 1.342 | 74      |
| 18    | 1.127 | 52      | 45    | 1.351 | 74      |
| 19    | 1.135 | 54      | 46    | 1.361 | 75      |
| 20    | 1.142 | 56      | 47    | 1.370 | 75      |
| 21    | 1.150 | 57      | 48    | 1.380 | 76      |
| 22    | 1.158 | 59      | 49    | 1.389 | 76      |
| 23    | 1.166 | 60      | 50    | 1.399 | 77      |
| 24    | 1.174 | 61      | 51    | 1.409 | 77      |
| 25    | 1.182 | 63      | 52    | 1.419 | 78      |
| 26    | 1.190 | 64      | 53    | 1.429 | 78      |

| <i>g</i> % | S.    | C.      | <i>g</i> % | S.    | C.      |
|------------|-------|---------|------------|-------|---------|
| 54         | 1.439 | 0.00079 | 78         | 1.709 | 0.00098 |
| 55         | 1.449 | 79      | 79         | 1.721 | 99      |
| 56         | 1.460 | 80      | 80         | 1.732 | 0.00102 |
| 57         | 1.470 | 81      | 81         | 1.744 | 104     |
| 58         | 1.481 | 82      | 82         | 1.754 | 106     |
| 59         | 1.492 | 82      | 83         | 1.765 | 107     |
| 60         | 1.502 | 83      | 84         | 1.775 | 108     |
| 61         | 1.513 | 84      | 85         | 1.784 | 108     |
| 62         | 1.524 | 84      | 86         | 1.793 | 108     |
| 63         | 1.535 | 85      | 87         | 1.801 | 107     |
| 64         | 1.547 | 86      | 88         | 1.808 | 107     |
| 65         | 1.558 | 87      | 89         | 1.814 | 106     |
| 66         | 1.569 | 87      | 90         | 1.820 | 105     |
| 67         | 1.580 | 88      | 91         | 1.825 | 104     |
| 68         | 1.592 | 89      | 92         | 1.829 | 103     |
| 69         | 1.603 | 89      | 93         | 1.833 | 102     |
| 70         | 1.615 | 90      | 94         | 1.836 | 101     |
| 71         | 1.627 | 91      | 95         | 1.839 | 100     |
| 72         | 1.639 | 92      | 96         | 1.841 | 0.00099 |
| 73         | 1.650 | 93      | 97         | 1.841 | 99      |
| 74         | 1.662 | 94      | 98         | 1.841 | 0.00100 |
| 75         | 1.674 | 95      | 99         | 1.839 | 101     |
| 76         | 1.686 | 96      | 100        | 1.836 | 102     |
| 77         | 1.698 | 97      |            |       |         |

## Dilution Table for Sulphuric Acid.

(Domke, *loc. cit.*) $S_{\frac{15}{4}}^{\frac{15}{4}}$  = required density of solution. $g\%$  = gms. of sulphuric acid in 100 gms. of solution of required density (to nearest 0.5%). $v$  = vol. in c.c. of acid of  $S_{\frac{15}{4}}^{\frac{15}{4}} = 1.84$  (i.e., 95% acid) at 15°C. to be added to 1000 c.c. of water at 15°C. $V$  = vol. of resulting solution in c.c. at 15°C. $dv$  = contraction due to admixture in c.c.

| $S_{\frac{15}{4}}^{\frac{15}{4}}$<br>4°C. | $g\%$ | $v$ | $V$ | $dv$ |
|---|-------|-----|-----|------|
|---|-------|-----|-----|------|

|      |      |     |      |    |
|------|------|-----|------|----|
| 1.01 | 1.5  | 9   | 1006 | 3  |
| .02  | 3.0  | 18  | 1012 | 6  |
| .03  | 4.5  | 27  | 1018 | 9  |
| .04  | 6.0  | 36  | 1025 | 11 |
| 1.05 | 7.5  | 46  | 1032 | 14 |
| .06  | 9.0  | 55  | 1039 | 16 |
| .07  | 10.5 | 65  | 1046 | 19 |
| .08  | 11.5 | 75  | 1053 | 22 |
| .09  | 13.0 | 86  | 1061 | 25 |
| 1.10 | 14.5 | 96  | 1069 | 27 |
| .11  | 16.0 | 107 | 1077 | 30 |
| .12  | 17.0 | 118 | 1086 | 32 |
| .13  | 18.5 | 129 | 1095 | 34 |
| .14  | 19.5 | 141 | 1104 | 37 |
| 1.15 | 21.0 | 153 | 1113 | 40 |
| .16  | 22.5 | 165 | 1123 | 42 |
| .17  | 23.5 | 177 | 1133 | 44 |
| .18  | 25.0 | 190 | 1143 | 47 |
| .19  | 26.0 | 203 | 1154 | 49 |
| 1.20 | 27.5 | 217 | 1165 | 52 |
| .21  | 28.5 | 231 | 1177 | 54 |
| .22  | 30.0 | 245 | 1189 | 56 |
| .23  | 31.0 | 260 | 1201 | 59 |
| .24  | 32.0 | 275 | 1214 | 61 |
| 1.25 | 33.5 | 291 | 1228 | 63 |
| .26  | 34.5 | 307 | 1242 | 65 |
| .27  | 36.0 | 324 | 1257 | 67 |
| .28  | 37.0 | 342 | 1272 | 70 |
| .29  | 38.0 | 360 | 1287 | 73 |

| $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $v$  | $V$  | $dv$ |
|--|-------|------|------|------|
| 1.30   | 39.0  | 378  | 1303 | 75   |
| .31  | 40.5  | 397  | 1320 | 77   |
| .32  | 41.5  | 417  | 1338 | 79   |
| .33  | 42.5  | 437  | 1356 | 81   |
| .34  | 44.0  | 458  | 1375 | 83   |
| 1.35   | 45.0  | 480  | 1394 | 86   |
| .36  | 46.0  | 502  | 1414 | 88   |
| .37  | 47.0  | 525  | 1434 | 91   |
| .38  | 48.0  | 548  | 1455 | 93   |
| .39  | 49.0  | 572  | 1477 | 95   |
| 1.40   | 50.0  | 598  | 1500 | 98   |
| .41  | 51.0  | 624  | 1523 | 101  |
| .42  | 52.0  | 651  | 1547 | 104  |
| .43  | 53.0  | 678  | 1572 | 106  |
| .44  | 54.0  | 707  | 1598 | 109  |
| 1.45   | 55.0  | 737  | 1624 | 113  |
| .46  | 56.0  | 768  | 1652 | 116  |
| .47  | 57.0  | 800  | 1681 | 119  |
| .48  | 58.0  | 834  | 1712 | 122  |
| .49  | 59.0  | 869  | 1744 | 125  |
| 1.50   | 60.0  | 905  | 1777 | 128  |
| .51  | 60.5  | 943  | 1811 | 132  |
| .52  | 61.5  | 983  | 1848 | 135  |
| .53  | 62.5  | 1025 | 1886 | 139  |
| .54  | 63.5  | 1069 | 1926 | 143  |
| 1.55   | 64.5  | 1115 | 1969 | 146  |
| .56  | 65.0  | 1163 | 2014 | 149  |
| .57  | 66.0  | 1214 | 2059 | 155  |
| .58  | 67.0  | 1266 | 2110 | 158  |
| .59  | 68.0  | 1325 | 2162 | 163  |
| 1.60   | 68.5  | 1386 | 2217 | 169  |
| .61  | 69.5  | 1450 | 2277 | 173  |
| .62  | 70.5  | 1517 | 2340 | 177  |
| .63  | 71.5  | 1589 | 2407 | 182  |
| .64  | 72.0  | 1666 | 2479 | 187  |
| 1.65   | 73.0  | 1749 | 2556 | 193  |
| .66  | 74.0  | 1839 | 2640 | 199  |
| .67  | 74.5  | 1934 | 2729 | 205  |
| .68  | 75.5  | 2038 | 2827 | 211  |
| .69  | 76.5  | 2151 | 2934 | 217  |
| 1.70   | 77.0  | 2276 | 3051 | 225  |



| $S_{\frac{15^{\circ}\text{C.}}{4^{\circ}\text{C.}}}$ | $g\%$ | $v.$  | $V$   | $dv.$ |
|--|-------|-------|-------|-------|
| .71  | 78.0  | 2414  | 3182  | 232   |
| .72  | 79.0  | 2566  | 3326  | 240   |
| .73  | 80.0  | 2737  | 3488  | 249   |
| .74  | 80.5  | 2932  | 3675  | 257   |
| 1.75   | 81.5  | 3158  | 3892  | 266   |
| .76  | 82.5  | 3424  | 4147  | 277   |
| .77  | 83.5  | 3745  | 4457  | 288   |
| .78  | 84.5  | 4147  | 4848  | 299   |
| .79  | 85.5  | 4675  | 5364  | 311   |
| 1.80   | 87.0  | 5425  | 6101  | 324   |
| .81  | 88.5  | 6599  | 7260  | 339   |
| .82  | 90.0  | 8762  | 9407  | 355   |
| .83  | 92.0  | 14507 | 15132 | 375   |

### Specific Gravity of Fuming Sulphuric Acid.

(Marshall, "Explosives," Vol. I, p. 103, 1917.)

$g\%$  = gms. of free  $\text{SO}_3$  in 100 gms. of acid.

$G$  = total gms. of  $\text{SO}_3$  in 100 gms. of acid.

| $g\%$ | $G\%$  | $S_{\frac{15^{\circ}\text{C.}}{15^{\circ}\text{C.}}}$ |
|-------|--------|---|
| 10    | 83.46  | 1.888   |
| 20    | 85.30  | 1.920   |
| 30    | 87.14  | 1.957   |
| 40    | 88.97  | 1.979   |
| 50    | 90.81  | 2.009   |
| 60    | 92.65  | 2.020   |
| 70    | 94.48  | 2.018   |
| 80    | 96.32  | 2.008   |
| 90    | 98.16  | 1.990   |
| 100   | 100.00 | 1.984   |

Note.—Oleum with 0% to 30% free  $\text{SO}_3$  is liquid at  $15^{\circ}\text{C}$ .

30% „ 56% „ „ solid „  
 56% „ 73% „ „ liquid „  
 73% „ 100% „ „ solid „

### Specific Gravity of Tannic Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, 27, 319.)

$g\%$  = gms. of  $C_{14}H_{10}O_9$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{17.5^\circ C.}{17.5^\circ C.}}$ | $g\%$ | $S_{\frac{17.5^\circ C.}{17.5^\circ C.}}$ | $g\%$ | $S_{\frac{17.5^\circ C.}{17.5^\circ C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.0040                                    | 8     | 1.0324                                    | 15    | 1.0614                                    |
| 2     | 080                                       | 9     | 365                                       | 16    | 656                                       |
| 3     | 120                                       | 10    | 406                                       | 17    | 698                                       |
| 4     | 160                                       | 11    | 447                                       | 18    | 740                                       |
| 5     | 201                                       | 12    | 489                                       | 19    | 782                                       |
| 6     | 242                                       | 13    | 530                                       | 20    | 824                                       |
| 7     | 283                                       | 14    | 572                                       |       |   |

### Specific Gravity of Tartar Emetic Solutions

(Gerlach, *Z. anal. Chem.*, 1888, 27, 315.)

$g\%$  = gms. of  $C_4H_4O_6K(SbO) + \frac{1}{2}H_2O$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{17.5^\circ C.}{17.5^\circ C.}}$ | $g\%$ | $S_{\frac{17.5^\circ C.}{17.5^\circ C.}}$ |
|-------|---|-------|---|
| 0.5   | 1.005                                     | 3.5   | 1.022                                     |
| 1.0   | 1.007                                     | 4.0   | 1.027                                     |
| 1.5   | 1.009                                     | 4.5   | 1.031                                     |
| 2.0   | 1.012                                     | 5.0   | 1.035                                     |
| 2.5   | 1.015                                     | 5.5   | 1.038                                     |
| 3.0   | 1.018                                     | 6.0   | 1.041                                     |

### Specific Gravity of Ordinary (d) Tartaric Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 295.)

$g\%$  = gms. of  $C_4H_6O_6$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{15^\circ C.}{15^\circ C.}}$ | $g\%$ | $S_{\frac{15^\circ C.}{15^\circ C.}}$ | $g\%$ | $S_{\frac{15^\circ C.}{15^\circ C.}}$ |
|-------|---------------------------------------|-------|---------------------------------------|-------|---------------------------------------|
| 1     | 1.0045                                | 20    | 1.0969                                | 40    | 1.2078                                |
| 2     | 090                                   | 22    | 1.1072                                | 41    | 198                                   |
| 4     | 179                                   | 24    | 175                                   | 44    | 317                                   |
| 6     | 273                                   | 26    | 282                                   | 46    | 441                                   |
| 8     | 371                                   | 28    | 393                                   | 48    | 568                                   |
| 10    | 469                                   | 30    | 505                                   | 50    | 696                                   |
| 12    | 565                                   | 32    | 615                                   | 52    | 828                                   |
| 14    | 661                                   | 34    | 726                                   | 54    | 961                                   |
| 16    | 761                                   | 36    | 840                                   | 56    | 1.3093                                |
| 18    | 865                                   | 38    | 959                                   |       |                                       |

## Specific Gravity of Tin (Stannic) Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 281.)

$g\%$  = gms. of  $\text{SnCl}_4 \cdot 5\text{H}_2\text{O}$  in 100 gms. of solution.

| $S_{g\% \frac{15^{\circ}\text{C.}}{15^{\circ}\text{C.}}}$ | $g\%$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ | $g\%$ | $S_{15^{\circ}\text{C.}}^{15^{\circ}\text{C.}}$ |       |
|---|-------|---|-------|---|-------|---|-------|
| 1   | 1.006 | 25  | 1.158 | 49  | 1.357 | 73  | 1.627 |
| 2   | 1.012 | 26  | 1.165 | 50  | 1.365 | 74  | 1.641 |
| 3   | 1.018 | 27  | 1.173 | 51  | 1.376 | 75  | 1.654 |
| 4   | 1.024 | 28  | 1.180 | 52  | 1.386 | 76  | 1.669 |
| 5   | 1.030 | 29  | 1.187 | 53  | 1.396 | 77  | 1.683 |
| 6   | 1.036 | 30  | 1.195 | 54  | 1.405 | 78  | 1.698 |
| 7   | 1.042 | 31  | 1.202 | 55  | 1.415 | 79  | 1.712 |
| 8   | 1.048 | 32  | 1.210 | 56  | 1.426 | 80  | 1.727 |
| 9   | 1.053 | 33  | 1.218 | 57  | 1.437 | 81  | 1.743 |
| 10  | 1.060 | 34  | 1.226 | 58  | 1.447 | 82  | 1.759 |
| 11  | 1.066 | 35  | 1.234 | 59  | 1.458 | 83  | 1.775 |
| 12  | 1.072 | 36  | 1.242 | 60  | 1.468 | 84  | 1.791 |
| 13  | 1.078 | 37  | 1.250 | 61  | 1.480 | 85  | 1.807 |
| 14  | 1.084 | 38  | 1.259 | 62  | 1.491 | 86  | 1.824 |
| 15  | 1.090 | 39  | 1.267 | 63  | 1.503 | 87  | 1.842 |
| 16  | 1.097 | 40  | 1.276 | 64  | 1.514 | 88  | 1.859 |
| 17  | 1.104 | 41  | 1.284 | 65  | 1.525 | 89  | 1.876 |
| 18  | 1.110 | 42  | 1.293 | 66  | 1.538 | 90  | 1.894 |
| 19  | 1.117 | 43  | 1.302 | 67  | 1.550 | 91  | 1.913 |
| 20  | 1.124 | 44  | 1.310 | 68  | 1.563 | 92  | 1.932 |
| 21  | 1.130 | 45  | 1.319 | 69  | 1.575 | 93  | 1.950 |
| 22  | 1.137 | 46  | 1.329 | 70  | 1.587 | 94  | 1.969 |
| 23  | 1.144 | 47  | 1.338 | 71  | 1.601 | 95  | 1.988 |
| 24  | 1.151 | 48  | 1.347 | 72  | 1.614 |   |       |

## Specific Gravity of Zinc Bromide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 285.)

$g\%$  = gms. of  $\text{ZnBr}_2$  in 100 gms. of solution.

| $g\%$ | $S_{19.5^\circ\text{C.}}^{19.5^\circ\text{C.}}$ | $g\%$ | $S_{19.5^\circ\text{C.}}^{19.5^\circ\text{C.}}$ |
|-------|---|-------|---|
| 5     | 1.045   | 35    | 1.400   |
| 10    | 1.093   | 40    | 1.475   |
| 15    | 1.196   | 45    | 1.560   |
| 20    | 1.204   | 50    | 1.650   |
| 25    | 1.265   | 55    | 1.755   |
| 30    | 1.330   | 60    | 1.875   |

## Specific Gravity of Zinc Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 283.)

$g\%$  = gms. of  $\text{ZnCl}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ |
|-------|---|-------|---|-------|---|-------|---|
| 1     | 1.010   | 16    | 1.146   | 31    | 1.304   | 46    | 1.500   |
| 2     | 1.020   | 17    | 1.155   | 32    | 1.316   | 47    | 1.518   |
| 3     | 1.029   | 18    | 1.165   | 33    | 1.329   | 48    | 1.533   |
| 4     | 1.037   | 19    | 1.175   | 34    | 1.340   | 49    | 1.550   |
| 5     | 1.045   | 20    | 1.186   | 35    | 1.352   | 50    | 1.566   |
| 6     | 1.053   | 21    | 1.196   | 36    | 1.366   | 51    | 1.581   |
| 7     | 1.063   | 22    | 1.207   | 37    | 1.380   | 52    | 1.600   |
| 8     | 1.072   | 23    | 1.218   | 38    | 1.392   | 53    | 1.615   |
| 9     | 1.082   | 24    | 1.228   | 39    | 1.406   | 54    | 1.631   |
| 10    | 1.091   | 25    | 1.238   | 40    | 1.420   | 55    | 1.650   |
| 11    | 1.100   | 26    | 1.249   | 41    | 1.432   | 56    | 1.669   |
| 12    | 1.110   | 27    | 1.260   | 42    | 1.446   | 57    | 1.686   |
| 13    | 1.120   | 28    | 1.270   | 43    | 1.460   | 58    | 1.704   |
| 14    | 1.128   | 29    | 1.281   | 44    | 1.473   | 59    | 1.724   |
| 15    | 1.137   | 30    | 1.291   | 45    | 1.488   | 60    | 1.740   |

## Specific Gravity of Zinc Iodide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 285.)

$g\%$  = gms. of  $\text{ZnI}_2$  in 100 gms. of solution.

| $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ | $g\%$ | $S_{\frac{19.5^\circ\text{C.}}{19.5^\circ\text{C.}}}$ |
|-------|---|-------|---|
| 5     | 1.045   | 45    | 1.560   |
| 10    | 1.091   | 50    | 1.650   |
| 15    | 1.140   | 55    | 1.754   |
| 20    | 1.196   | 60    | 1.875   |
| 25    | 1.255   | 65    | 2.020   |
| 30    | 1.368   | 70    | 2.180   |
| 35    | 1.390   | 75    | 2.360   |
| 40    | 1.420   |       |   |

# Specific Gravity of Zinc Nitrate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, 27, 310.)

$g\%$  = gms. of  $\text{Zn}(\text{NO}_3)_2$  in 100 gms. of solution.

| $g\%$ | $\frac{S_{17.5^\circ\text{C.}}}{17.5^\circ\text{C.}}$ | $g\%$ | $\frac{S_{17.5^\circ\text{C.}}}{17.5^\circ\text{C.}}$ | $g\%$ | $\frac{S_{17.5^\circ\text{C.}}}{17.5^\circ\text{C.}}$ | $g\%$ | $\frac{S_{17.5^\circ\text{C.}}}{17.5^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|-------|---|
| 1     | 1.0099  | 14    | 1.1376  | 27    | 1.2892  | 40    | 1.4572  |
| 2     | 198   | 15    | 476   | 28    | 1.3018  | 41    | 707   |
| 3     | 297   | 16    | 586   | 29    | 144   | 42    | 844   |
| 4     | 396   | 17    | 696   | 30    | 268   | 43    | 981   |
| 5     | 496   | 18    | 806   | 31    | 396   | 44    | 1.5118  |
| 6     | 590   | 19    | 916   | 32    | 524   | 45    | 258   |
| 7     | 684   | 20    | 1.2024  | 33    | 652   | 46    | 403   |
| 8     | 778   | 21    | 147   | 34    | 780   | 47    | 548   |
| 9     | 872   | 22    | 270   | 35    | 906   | 48    | 693   |
| 10    | 968   | 23    | 393   | 36    | 1.4039  | 49    | 838   |
| 11    | 1.1070  | 24    | 516   | 37    | 172   | 50    | 984   |
| 12    | 172   | 25    | 640   | 38    | 305   |       |   |
| 13    | 274   | 26    | 766   | 39    | 438   |       |   |

# Specific Gravity of Zinc Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, 8, 288.)

$g\%$  = gms. of  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$  in 100 gms. of solution.

| $g\%$ | $\frac{S_{15^\circ\text{C.}}}{15^\circ\text{C.}}$ | $g\%$ | $\frac{S_{15^\circ\text{C.}}}{15^\circ\text{C.}}$ | $g\%$ | $\frac{S_{15^\circ\text{C.}}}{15^\circ\text{C.}}$ |
|-------|---|-------|---|-------|---|
| 1     | 1.006   | 21    | 1.130   | 41    | 1.280   |
| 2     | 13  | 22    | 37  | 42    | 88  |
| 3     | 19  | 23    | 43  | 43    | 95  |
| 4     | 24  | 24    | 50  | 44    | 1.304   |
| 5     | 29  | 25    | 57  | 45    | 10  |
| 6     | 35  | 26    | 64  | 46    | 20  |
| 7     | 41  | 27    | 71  | 47    | 30  |
| 8     | 47  | 28    | 79  | 48    | 37  |
| 9     | 53  | 29    | 85  | 49    | 46  |
| 10    | 59  | 30    | 93  | 50    | 53  |
| 11    | 66  | 31    | 1.200   | 51    | 62  |
| 12    | 73  | 32    | 09  | 52    | 70  |
| 13    | 79  | 33    | 16  | 53    | 80  |
| 14    | 85  | 34    | 24  | 54    | 90  |
| 15    | 90  | 35    | 31  | 55    | 99  |
| 16    | 97  | 36    | 40  | 56    | 1.406   |
| 17    | 1.103   | 37    | 46  | 57    | 16  |
| 18    | 10  | 38    | 55  | 58    | 25  |
| 19    | 16  | 39    | 63  | 59    | 35  |
| 20    | 24  | 40    | 71  | 60    | 45  |

# Universal Dilution Table.

If 100 volumes of solution of the percentage strength by volume shewn in the first column are diluted until the total volume has one of the values given in the body of the table the strength of the diluted solution is that given at the head of the column above the volume of the diluted solution. For example, suppose that it is required to dilute a solution whose strength is 75% by volume to a strength of 20% by volume. From the table it will be seen that each 100 cc. of the original solution must be diluted until the total volume of the solution is 375.00 cc.

If it is desired to make 1000 cc. of the 20% solution from the 75% solution then  $100 \times \frac{1000}{375}$  i.e., 266.67 cc. of the latter must be diluted to 1000 cc. The initial and final temperatures must be the same.

## PERCENTAGE BY VOLUME AFTER DILUTION.

|     | 95.    | 90.    | 85.    | 80.    | 75.    | 70.    | 65.    | 60.    | 55.    | 50.    | 45.    | 40.    | 35.    | 30.    | 25.    | 20.    | 15.    | 10.     | 5.      |
|-----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|---------|
| 100 | 105.26 | 111.11 | 117.65 | 125.00 | 133.33 | 142.86 | 153.85 | 166.67 | 181.82 | 200.00 | 222.22 | 250.00 | 285.71 | 333.33 | 400.00 | 500.00 | 666.67 | 1000.00 | 2000.00 |
| 95  | —      | 105.56 | 111.76 | 118.75 | 126.67 | 135.71 | 146.15 | 158.33 | 172.73 | 190.00 | 211.11 | 237.50 | 271.43 | 316.67 | 380.00 | 475.00 | 633.33 | 950.00  | 1900.00 |
| 90  | —      | —      | 105.88 | 112.50 | 120.00 | 128.57 | 138.46 | 150.00 | 163.64 | 180.00 | 200.00 | 225.00 | 257.14 | 300.00 | 360.00 | 450.00 | 600.00 | 900.00  | 1800.00 |
| 85  | —      | —      | —      | 106.25 | 113.33 | 121.43 | 130.77 | 141.67 | 154.54 | 170.00 | 188.89 | 212.50 | 242.86 | 283.33 | 340.00 | 425.00 | 566.67 | 850.00  | 1700.00 |
| 80  | —      | —      | —      | —      | 106.67 | 114.29 | 123.08 | 133.33 | 145.45 | 160.00 | 177.78 | 200.00 | 228.57 | 266.67 | 320.00 | 400.00 | 533.33 | 800.00  | 1600.00 |
| 75  | —      | —      | —      | —      | —      | 107.14 | 115.38 | 125.00 | 136.36 | 150.00 | 166.67 | 187.50 | 221.43 | 250.00 | 300.00 | 375.00 | 500.00 | 750.00  | 1500.00 |
| 70  | —      | —      | —      | —      | —      | —      | 107.69 | 116.67 | 127.27 | 140.00 | 155.56 | 175.00 | 200.00 | 233.33 | 280.00 | 350.00 | 466.67 | 700.00  | 1400.00 |
| 65  | —      | —      | —      | —      | —      | —      | —      | 108.33 | 118.18 | 130.00 | 144.44 | 162.50 | 185.71 | 216.67 | 260.00 | 325.00 | 433.33 | 650.00  | 1300.00 |
| 60  | —      | —      | —      | —      | —      | —      | —      | —      | 109.09 | 120.00 | 133.33 | 150.00 | 171.43 | 200.00 | 240.00 | 300.00 | 400.00 | 600.00  | 1200.00 |
| 55  | —      | —      | —      | —      | —      | —      | —      | —      | —      | 110.00 | 122.22 | 137.50 | 157.14 | 183.33 | 220.00 | 275.00 | 366.67 | 550.00  | 1100.00 |
| 50  | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | 111.11 | 125.00 | 142.86 | 166.67 | 200.00 | 250.00 | 333.33 | 500.00  | 1000.00 |
| 45  | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | 112.50 | 128.57 | 150.00 | 180.00 | 225.00 | 300.00 | 450.00  | 900.00  |
| 40  | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | 114.29 | 133.33 | 160.00 | 200.00 | 266.67 | 400.00  | 800.00  |
| 35  | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | 116.67 | 140.00 | 175.00 | 233.33 | 350.00  | 700.00  |
| 30  | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | 120.00 | 150.00 | 200.00 | 300.00  | 600.00  |
| 25  | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | 125.00 | 166.67 | 250.00  | 500.00  |
| 20  | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | 133.33 | 200.00  | 400.00  |
| 15  | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | 150.00  | 300.00  |
| 10  | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —      | —       | 200.00  |

## Densities of Gases.

In gms. per litre (1000.027 cc.) at 0°C. under a pressure of 760 mm. of mercury at 0°C. and lat. 45° at sea-level. Where references to observers are not given the figures are not recent and not, presumably, of the same accuracy; where two observers are mentioned, the value given is the mean.

| Gas.   | Density observed. |                  |                 | Observer.                   |
|--|-------------------|------------------|-----------------|-----------------------------|
|  | Mol. wt.<br>O=16  | Rel.<br>to O=16. | Gms./<br>litre. |                             |
| Acetylene $\text{C}_2\text{H}_2$ .....                   | 26.02             | 13.094           | 1.1695          | Maass /18                   |
| Air .....  | —                 | 14.475           | 1.2928          | Leduc /17                   |
| Ammonia $\text{NH}_3$ .....                              | 17.03             | 8.630            | 0.7708          | Perman /06                  |
| Argon A .....  | 39.88             | 1.9964           | 1.7831          | { Leduc /18<br>Schultze /15 |
| Arsine $\text{AsH}_3$ .....                              | 77.98             | 39.0             | 3.48            |                             |
| Boron chloride $\text{BCl}_3$ .....                      | 117.4             | 57.0             | 5.08            |                             |
| „ fluoride $\text{BF}_3$ .....                           | 68.0              | 33.4             | 2.99            |                             |
| Butane $\text{C}_4\text{H}_{10}$ .....                   | 58.10             | 29.11            | 2.601           |                             |
| Carbon dioxide $\text{CO}_2$ .....                       | 44.00             | 22.133           | 1.9768          | Guye /05                    |
| „ monoxide $\text{CO}$ .....                             | 28.00             | 14.000           | 1.2504          | Rayleigh /98                |
| „ oxychloride $\text{COCl}_2$ at<br>100°C. ....          | 98.92             | 50.7             | 4.53            |                             |
| „ oxysulphide $\text{COS}$ ....                          | 60.06             | 30.4             | 2.72            |                             |
| Chlorine $\text{Cl}_2$ .....                             | 70.92             | 35.98            | 3.214           | Jacquerod /13               |
| „ monoxide $\text{Cl}_2\text{O}$ .....                   | 86.92             | 43.54            | 3.889           |                             |
| „ dioxide $\text{ClO}_2$ .....                           | 67.46             | 33.8             | 3.02            |                             |
| Cynogen $\text{C}_2\text{N}_2$ .....                     | 52.02             | 26.16            | 2.337           |                             |
| Ethane $\text{C}_2\text{H}_6$ .....                      | 30.06             | 15.187           | 1.3565          | Stahrfoos /18               |
| Ethylamine $\text{C}_2\text{H}_7\text{N}$ at 100°C...    | 45.08             | 22.75            | 2.032           |                             |
| Ethyl chloride $\text{C}_2\text{H}_5\text{Cl}$ at 100°C. | 64.51             | 32.11            | 2.868           |                             |
| Ethylene $\text{C}_2\text{H}_4$ .....                    | 28.04             | 14.111           | 1.2603          | Bateucas /18                |
| Fluorine $\text{F}_2$ .....                              | 38.0              | 19.0             | 1.69            |                             |

| Gas.   | Density observed. |        |                          | Observer.                 |
|--|-------------------|--------|--------------------------|---------------------------|
|  | Mol. wt.<br>O=16  | Rel.   | Gms./<br>to O=16. litre. |                           |
| Helium He .....  | 4.00              | 1.9984 | 0.17849                  | Taylor /17                |
| Hydrogen H <sub>2</sub> .....                            | 2.016             | 1.0062 | 0.08987                  | Morley                    |
| „ bromide HBr .....                                      | 80.93             | 40.802 | 3.6442                   | { Moles /16<br>Murray /17 |
| „ chloride HCl .....                                     | 36.47             | 18.360 | 1.6398                   |                           |
| „ fluoride HF at 100°C.                                  | 20.0              | 10.32  | 0.922                    | { Guye                    |
| „ iodide HI .....  | 127.93            | 64.2   | 5.74                     |                           |
| „ selenide H <sub>2</sub> Se .....                       | 81.2              | 41.107 | 3.6715                   | { Bruylants /12           |
| „ sulphide H <sub>2</sub> S .....                        | 34.08             | 17.23  | 1.539                    |                           |
| „ telluride H <sub>2</sub> Te.....                       | 129.5             | 65.0   | 5.80                     |                           |
| Krypton Kr .....   | 82.92             | 41.52  | 3.708                    | Moore /08                 |
| Methane CH <sub>4</sub> .....                            | 16.04             | 8.025  | 0.7168                   | Baume /09                 |
| Methylamine CH <sub>5</sub> N .....                      | 31.05             | 15.62  | 1.395                    |                           |
| Methyl chloride CH <sub>3</sub> Cl .....                 | 50.49             | 25.04  | 2.236                    |                           |
| „ ether C <sub>2</sub> H <sub>6</sub> O .....            | 46.06             | 23.63  | 2.1103                   | Naass /18                 |
| „ fluoride CH <sub>3</sub> F .....                       | 34.0              | 17.30  | 1.5451                   | Moles /21                 |
| Neon Ne .....  | 20.2              | 10.07  | 0.8986                   | Leduc /14                 |
| Nitric oxide NO .....                                    | 30.01             | 15.005 | 1.3402                   | Guy, Guye                 |
| Nitrogen N <sub>2</sub> .....                            | 28.02             | 14.004 | 1.2507                   | Gry, Moles /22            |
| Nitrosyl chloride NOCl .....                             | 65.47             | 33.42  | 2.985                    |                           |
| Nitrogen peroxide N <sub>2</sub> O <sub>4</sub> at 26.7° | 92.02             | 38.3   | 3.42                     |                           |
| „ „ „ 60.2°  |                   | 30.1   |                          |                           |
| „ „ „ 100.1°   |                   | 24.3   |                          |                           |
| „ „ NO <sub>2</sub> at 140°                              | 46.01             | 23.0   | 2.05                     |                           |
| Nitrous oxide N <sub>2</sub> O .....                     | 44.02             | 22.143 | 1.9777                   | Guye                      |
| Oxygen O <sub>2</sub> .....                              | 32.00             | 16.000 | 1.42906                  | Germann /14               |
| Phosphine PH <sub>3</sub> .....                          | 34.06             | 17.57  | 1.569                    |                           |
| Phosphorus chlorofluoride                                |                   |        |                          |                           |
| „ PCl <sub>2</sub> F <sub>3</sub> .....                  | 158.9             | 78.2   | 6.98                     |                           |
| „ oxyfluoride POF <sub>3</sub> .....                     | 104.0             | 53.25  | 4.75                     |                           |
| „ pentafluoride PF <sub>5</sub> .....                    | 126.0             | 65.0   | 5.80                     |                           |
| „ trifluoride PF <sub>3</sub> .....                      | 88.0              | 43.7   | 3.91                     |                           |
| Propylene C <sub>3</sub> H <sub>6</sub> .....            | 39.04             | 21.67  | 1.936                    |                           |
| Silicon fluoride SiF <sub>4</sub> .....                  | 104.3             | 52.42  | 4.684                    | Germann /7                |
| Sulphur dioxide SO <sub>2</sub> .....                    | 64.06             | 32.767 | 2.9266                   | { Berthelot<br>Jacquerod  |
| Xenon X .....  | 130.2             | 65.51  | 5.851                    |                           |
|  |                   |        |                          | Moore /08                 |



## Density of Air half saturated with Water Vapour.

In mgms. per cc. (Donaldson, 1911, unpublished).

| °C. | Pressure in mm. of mercury. |       |       |       |       |       |       |       |
|-----|-----------------------------|-------|-------|-------|-------|-------|-------|-------|
|     | 740                         | 745   | 750   | 755   | 760   | 765   | 770   | 775   |
| 9   | 1.216                       | 1.224 | 1.233 | 1.241 | 1.249 | 1.257 | 1.265 | 1.274 |
| 11  | 1.207                       | 1.215 | 1.223 | 1.232 | 1.240 | 1.248 | 1.256 | 1.264 |
| 13  | 1.198                       | 1.206 | 1.214 | 1.223 | 1.231 | 1.239 | 1.247 | 1.255 |
| 15  | 1.189                       | 1.197 | 1.206 | 1.214 | 1.222 | 1.230 | 1.238 | 1.246 |
| 17  | 1.181                       | 1.189 | 1.197 | 1.205 | 1.213 | 1.221 | 1.229 | 1.237 |
| 19  | 1.172                       | 1.180 | 1.188 | 1.196 | 1.204 | 1.212 | 1.220 | 1.228 |
| 21  | 1.163                       | 1.171 | 1.179 | 1.187 | 1.195 | 1.203 | 1.211 | 1.219 |
| 23  | 1.155                       | 1.163 | 1.170 | 1.178 | 1.186 | 1.194 | 1.202 | 1.210 |
| 25  | 1.146                       | 1.154 | 1.162 | 1.170 | 1.177 | 1.185 | 1.193 | 1.201 |
| 27  | 1.138                       | 1.145 | 1.153 | 1.161 | 1.169 | 1.176 | 1.184 | 1.192 |

## Tables for Use in Gas-Volumetric Analysis.

In the following pages are given tables which have been deduced for various analytical operations; it should be noticed that these do not give the actual density of the moist gas, but the weight of the gas alone contained therein, that of the water having been subtracted. The error due to inaccuracy of the reduction to N.T.P. and to use of incorrect values of density may amount to 0.3% in the worst cases for the  $\text{CO}_2$  table; the others are accurate to about 0.1%. The hydrogen table is useful not only in the determination of equivalents of metals, etc., but also in calculating vapour densities from the volume of air displaced in Victor Meyer's method.

When greater accuracy is required the Tables for Correction to N.T.P. should be used in connection with the values of normal density given above.

# Carbon Dioxide.

Weight, in mgms., of Carbon Dioxide in 1 cc. of the Gas saturated with Aqueous Vapour.  
(Regnault).

| t°C. | 740   | 744   | 748   | 750   | 752   | 754   | 756   | 758   | 760   | 762   | 764   | 766   | 768   | 770   |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 10   | 1.824 | 1.834 | 1.844 | 1.849 | 1.854 | 1.859 | 1.864 | 1.869 | 1.874 | 1.879 | 1.884 | 1.889 | 1.894 | 1.899 |
| 11   | 16    | 26    | 36    | 41    | 46    | 51    | 56    | 61    | 66    | 71    | 76    | 81    | 86    | 91    |
| 12   | 08    | 18    | 28    | 33    | 38    | 43    | 48    | 53    | 58    | 63    | 68    | 73    | 78    | 83    |
| 13   | 00    | 10    | 20    | 25    | 30    | 35    | 40    | 45    | 50    | 55    | 60    | 65    | 70    | 75    |
| 14   | 1.792 | 02    | 12    | 17    | 22    | 27    | 32    | 37    | 42    | 47    | 52    | 56    | 61    | 66    |
| 15   | 84    | 1.794 | 04    | 09    | 14    | 18    | 23    | 28    | 33    | 38    | 43    | 48    | 53    | 58    |
| 16   | 76    | 86    | 1.796 | 00    | 05    | 10    | 15    | 20    | 25    | 30    | 35    | 39    | 44    | 49    |
| 17   | 68    | 77    | 87    | 1.792 | 1.797 | 02    | 06    | 11    | 16    | 21    | 26    | 31    | 36    | 41    |
| 18   | 59    | 69    | 79    | 84    | 88    | 1.793 | 1.798 | 03    | 08    | 13    | 18    | 22    | 27    | 32    |
| 19   | 51    | 60    | 70    | 75    | 80    | 85    | 89    | 1.794 | 1.799 | 04    | 09    | 14    | 19    | 23    |
| 20   | 42    | 52    | 61    | 66    | 71    | 76    | 81    | 86    | 91    | 1.795 | 00    | 05    | 10    | 15    |
| 21   | 34    | 43    | 53    | 58    | 63    | 67    | 72    | 77    | 82    | 87    | 1.791 | 1.796 | 01    | 06    |
| 22   | 25    | 35    | 44    | 49    | 54    | 59    | 63    | 68    | 73    | 78    | 83    | 87    | 1.792 | 1.797 |
| 23   | 16    | 26    | 35    | 40    | 45    | 50    | 55    | 59    | 64    | 69    | 74    | 78    | 83    | 88    |
| 24   | 08    | 17    | 27    | 31    | 36    | 41    | 46    | 50    | 55    | 60    | 65    | 69    | 74    | 79    |
| 25   | 1.699 | 08    | 18    | 22    | 27    | 32    | 36    | 41    | 46    | 51    | 55    | 60    | 65    | 70    |

| mm. | 10°   | 11°   | 12°   | 13°   | 14°   | 15°   | 16°   | 17°   | 18°   | 19°   | 20°   | 21°   | 22°   | 23°   | 24°   | 25°   |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 720 | 81.15 | 80.79 | 80.44 | 80.09 | 79.73 | 79.35 | 78.98 | 78.61 | 78.23 | 77.86 | 77.50 | 77.10 | 76.70 | 76.30 | 75.91 | 75.50 |
| 722 | 81.38 | 81.02 | 80.67 | 80.32 | 79.96 | 79.57 | 79.20 | 78.83 | 78.45 | 78.08 | 77.72 | 77.32 | 76.92 | 76.52 | 76.13 | 75.72 |
| 724 | 81.61 | 81.25 | 80.89 | 80.54 | 80.18 | 79.80 | 79.42 | 79.05 | 78.67 | 78.30 | 77.94 | 77.54 | 77.14 | 76.74 | 76.34 | 75.93 |
| 726 | 81.84 | 81.48 | 81.12 | 80.77 | 80.41 | 80.02 | 79.65 | 79.28 | 78.89 | 78.52 | 78.16 | 77.76 | 77.35 | 76.96 | 76.56 | 76.15 |
| 728 | 82.07 | 81.70 | 81.34 | 80.99 | 80.63 | 80.25 | 79.87 | 79.50 | 79.11 | 78.74 | 78.38 | 77.98 | 77.57 | 77.18 | 76.78 | 76.37 |
| 730 | 82.29 | 81.93 | 81.57 | 81.22 | 80.86 | 80.47 | 80.10 | 79.72 | 79.34 | 78.96 | 78.60 | 78.20 | 77.79 | 77.40 | 77.00 | 76.58 |
| 732 | 82.52 | 82.16 | 81.80 | 81.45 | 81.08 | 80.70 | 80.32 | 79.94 | 79.56 | 79.18 | 78.82 | 78.42 | 78.01 | 77.61 | 77.22 | 76.80 |
| 734 | 82.75 | 82.39 | 82.03 | 81.67 | 81.31 | 80.92 | 80.54 | 80.17 | 79.78 | 79.40 | 79.04 | 78.63 | 78.23 | 77.83 | 77.43 | 77.02 |
| 736 | 82.98 | 82.61 | 82.25 | 81.90 | 81.53 | 81.14 | 80.77 | 80.39 | 80.00 | 79.62 | 79.26 | 78.85 | 78.45 | 78.05 | 77.65 | 77.23 |
| 738 | 83.21 | 82.84 | 82.48 | 82.12 | 81.76 | 81.37 | 80.99 | 80.61 | 80.22 | 79.84 | 79.50 | 79.07 | 78.67 | 78.27 | 77.87 | 77.45 |
| 740 | 83.44 | 83.07 | 82.71 | 82.35 | 81.98 | 81.59 | 81.21 | 80.83 | 80.44 | 80.07 | 79.71 | 79.29 | 78.89 | 78.49 | 78.08 | 77.67 |
| 742 | 83.65 | 83.30 | 82.93 | 82.58 | 82.21 | 81.82 | 81.44 | 81.06 | 80.67 | 80.29 | 79.93 | 79.51 | 79.11 | 78.71 | 78.30 | 77.88 |
| 744 | 83.89 | 83.52 | 83.16 | 82.80 | 82.43 | 82.04 | 81.66 | 81.28 | 80.89 | 80.51 | 80.15 | 79.73 | 79.33 | 78.92 | 78.52 | 78.10 |
| 746 | 84.12 | 83.75 | 83.39 | 83.03 | 82.66 | 82.27 | 81.88 | 81.50 | 81.11 | 80.73 | 80.37 | 79.95 | 79.55 | 79.14 | 78.74 | 78.32 |
| 748 | 84.35 | 83.98 | 83.61 | 83.25 | 82.89 | 82.49 | 82.11 | 81.73 | 81.34 | 80.95 | 80.59 | 80.17 | 79.76 | 79.36 | 78.96 | 78.53 |
| 750 | 84.58 | 84.21 | 83.84 | 83.48 | 83.11 | 82.71 | 82.33 | 81.95 | 81.56 | 81.17 | 80.81 | 80.39 | 79.98 | 79.58 | 79.17 | 78.75 |
| 752 | 84.81 | 84.43 | 84.07 | 83.71 | 83.34 | 82.94 | 82.55 | 82.17 | 81.78 | 81.40 | 81.02 | 80.61 | 80.20 | 79.80 | 79.39 | 78.97 |
| 754 | 85.04 | 84.66 | 84.29 | 83.93 | 83.56 | 83.16 | 82.78 | 82.39 | 82.00 | 81.62 | 81.25 | 80.83 | 80.42 | 80.01 | 79.60 | 79.18 |
| 756 | 85.26 | 84.89 | 84.52 | 84.16 | 83.79 | 83.39 | 83.00 | 82.62 | 82.22 | 81.84 | 81.47 | 81.05 | 80.64 | 80.23 | 79.83 | 79.40 |
| 758 | 85.49 | 85.12 | 84.75 | 84.38 | 84.01 | 83.61 | 83.22 | 82.84 | 82.44 | 82.06 | 81.69 | 81.27 | 80.86 | 80.45 | 80.04 | 79.62 |
| 760 | 85.72 | 85.34 | 84.97 | 84.61 | 84.24 | 83.84 | 83.45 | 83.06 | 82.67 | 82.28 | 81.91 | 81.48 | 81.08 | 80.67 | 80.26 | 79.83 |
| 762 | 85.95 | 85.57 | 85.20 | 84.84 | 84.46 | 84.06 | 83.67 | 83.29 | 82.89 | 82.50 | 82.13 | 81.70 | 81.30 | 80.89 | 80.48 | 80.05 |
| 764 | 86.18 | 85.80 | 85.42 | 85.06 | 84.69 | 84.28 | 83.90 | 83.51 | 83.11 | 82.72 | 82.35 | 81.92 | 81.52 | 81.11 | 80.70 | 80.27 |
| 766 | 86.41 | 86.03 | 85.65 | 85.29 | 84.91 | 84.51 | 84.12 | 83.73 | 83.33 | 82.94 | 82.57 | 82.14 | 81.74 | 81.32 | 80.91 | 80.49 |
| 768 | 86.63 | 86.25 | 85.88 | 85.51 | 85.14 | 84.73 | 84.34 | 83.95 | 83.55 | 83.17 | 82.79 | 82.36 | 81.96 | 81.54 | 81.13 | 80.70 |
| 770 | 86.86 | 86.48 | 86.11 | 85.74 | 85.36 | 84.96 | 84.57 | 84.17 | 83.78 | 83.39 | 83.01 | 82.58 | 82.17 | 81.76 | 81.35 | 80.92 |

# **Oxygen.** Weight, in mgms., of Oxygen in 1 cc. of the Gas saturated with Aqueous Vapour. (Vanino).

| mm. | 10°   | 11°   | 12°   | 13°   | 14°   | 15°   | 16°   | 17°   | 18°   | 19°   | 20°   | 21°   | 22°   | 23°   | 24°   | 25°   |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 700 | 1.253 | 1.248 | 1.242 | 1.237 | 1.231 | 1.225 | 1.219 | 1.214 | 1.208 | 1.202 | 1.196 | 1.190 | 1.184 | 1.178 | 1.172 | 1.165 |
| 702 | 1.257 | 1.251 | 1.246 | 1.240 | 1.234 | 1.229 | 1.223 | 1.217 | 1.211 | 1.205 | 1.200 | 1.194 | 1.188 | 1.181 | 1.175 | 1.169 |
| 704 | 1.260 | 1.255 | 1.249 | 1.244 | 1.238 | 1.232 | 1.227 | 1.221 | 1.215 | 1.209 | 1.203 | 1.197 | 1.191 | 1.185 | 1.179 | 1.172 |
| 706 | 1.264 | 1.259 | 1.253 | 1.247 | 1.241 | 1.236 | 1.230 | 1.224 | 1.218 | 1.212 | 1.207 | 1.201 | 1.194 | 1.188 | 1.182 | 1.176 |
| 708 | 1.268 | 1.262 | 1.256 | 1.251 | 1.245 | 1.239 | 1.234 | 1.228 | 1.222 | 1.216 | 1.210 | 1.204 | 1.198 | 1.192 | 1.186 | 1.179 |
| 710 | 1.271 | 1.266 | 1.260 | 1.254 | 1.249 | 1.243 | 1.237 | 1.231 | 1.225 | 1.219 | 1.214 | 1.208 | 1.202 | 1.195 | 1.189 | 1.183 |
| 712 | 1.275 | 1.269 | 1.264 | 1.258 | 1.252 | 1.247 | 1.241 | 1.235 | 1.229 | 1.223 | 1.217 | 1.211 | 1.205 | 1.199 | 1.192 | 1.186 |
| 714 | 1.279 | 1.273 | 1.267 | 1.262 | 1.256 | 1.250 | 1.244 | 1.239 | 1.233 | 1.227 | 1.221 | 1.215 | 1.208 | 1.202 | 1.196 | 1.190 |
| 716 | 1.282 | 1.277 | 1.271 | 1.265 | 1.259 | 1.254 | 1.248 | 1.242 | 1.236 | 1.230 | 1.224 | 1.218 | 1.212 | 1.206 | 1.199 | 1.193 |
| 718 | 1.286 | 1.280 | 1.274 | 1.269 | 1.263 | 1.257 | 1.251 | 1.245 | 1.240 | 1.234 | 1.228 | 1.221 | 1.215 | 1.209 | 1.203 | 1.196 |
| 720 | 1.289 | 1.284 | 1.278 | 1.272 | 1.267 | 1.261 | 1.255 | 1.249 | 1.243 | 1.237 | 1.231 | 1.225 | 1.219 | 1.213 | 1.206 | 1.200 |
| 722 | 1.293 | 1.287 | 1.282 | 1.276 | 1.270 | 1.264 | 1.259 | 1.253 | 1.247 | 1.241 | 1.235 | 1.229 | 1.222 | 1.216 | 1.210 | 1.203 |
| 724 | 1.297 | 1.291 | 1.285 | 1.280 | 1.274 | 1.268 | 1.262 | 1.256 | 1.250 | 1.244 | 1.238 | 1.232 | 1.226 | 1.220 | 1.213 | 1.207 |
| 726 | 1.300 | 1.295 | 1.289 | 1.283 | 1.277 | 1.271 | 1.266 | 1.260 | 1.254 | 1.248 | 1.242 | 1.236 | 1.229 | 1.223 | 1.217 | 1.210 |
| 728 | 1.304 | 1.298 | 1.292 | 1.287 | 1.281 | 1.275 | 1.269 | 1.263 | 1.257 | 1.251 | 1.245 | 1.239 | 1.233 | 1.226 | 1.220 | 1.213 |
| 730 | 1.308 | 1.302 | 1.296 | 1.290 | 1.284 | 1.279 | 1.273 | 1.267 | 1.261 | 1.255 | 1.249 | 1.243 | 1.236 | 1.230 | 1.224 | 1.217 |
| 732 | 1.311 | 1.306 | 1.300 | 1.294 | 1.288 | 1.282 | 1.276 | 1.270 | 1.264 | 1.258 | 1.252 | 1.246 | 1.240 | 1.233 | 1.227 | 1.221 |
| 734 | 1.315 | 1.309 | 1.303 | 1.298 | 1.292 | 1.286 | 1.280 | 1.274 | 1.268 | 1.262 | 1.256 | 1.250 | 1.243 | 1.237 | 1.231 | 1.224 |
| 736 | 1.318 | 1.313 | 1.307 | 1.301 | 1.295 | 1.289 | 1.283 | 1.277 | 1.271 | 1.265 | 1.259 | 1.253 | 1.247 | 1.240 | 1.234 | 1.227 |
| 738 | 1.322 | 1.316 | 1.310 | 1.305 | 1.299 | 1.293 | 1.287 | 1.281 | 1.275 | 1.269 | 1.263 | 1.256 | 1.250 | 1.244 | 1.237 | 1.231 |

| mm. | 10°   | 11°   | 12°   | 13°   | 14°   | 15°   | 16°   | 17°   | 18°   | 19°   | 20°   | 21°   | 22°   | 23°   | 24°   | 25°   |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 740 | 1.326 | 1.320 | 1.314 | 1.308 | 1.302 | 1.296 | 1.290 | 1.285 | 1.278 | 1.272 | 1.266 | 1.260 | 1.254 | 1.247 | 1.241 | 1.234 |
| 742 | 1.329 | 1.324 | 1.318 | 1.312 | 1.306 | 1.300 | 1.294 | 1.289 | 1.281 | 1.276 | 1.270 | 1.263 | 1.257 | 1.251 | 1.244 | 1.238 |
| 744 | 1.333 | 1.327 | 1.321 | 1.315 | 1.309 | 1.304 | 1.298 | 1.292 | 1.285 | 1.279 | 1.273 | 1.266 | 1.261 | 1.254 | 1.248 | 1.241 |
| 746 | 1.337 | 1.331 | 1.325 | 1.319 | 1.313 | 1.307 | 1.301 | 1.295 | 1.289 | 1.283 | 1.277 | 1.270 | 1.264 | 1.258 | 1.251 | 1.245 |
| 748 | 1.340 | 1.334 | 1.328 | 1.323 | 1.317 | 1.311 | 1.305 | 1.299 | 1.292 | 1.286 | 1.280 | 1.274 | 1.267 | 1.261 | 1.255 | 1.248 |
| 750 | 1.344 | 1.338 | 1.332 | 1.326 | 1.320 | 1.314 | 1.308 | 1.302 | 1.296 | 1.290 | 1.284 | 1.277 | 1.271 | 1.264 | 1.258 | 1.252 |
| 752 | 1.347 | 1.342 | 1.336 | 1.330 | 1.324 | 1.318 | 1.312 | 1.306 | 1.300 | 1.293 | 1.287 | 1.281 | 1.274 | 1.268 | 1.261 | 1.255 |
| 754 | 1.351 | 1.345 | 1.339 | 1.333 | 1.327 | 1.321 | 1.315 | 1.309 | 1.303 | 1.297 | 1.291 | 1.284 | 1.278 | 1.272 | 1.265 | 1.258 |
| 756 | 1.355 | 1.349 | 1.343 | 1.337 | 1.331 | 1.325 | 1.319 | 1.313 | 1.307 | 1.300 | 1.294 | 1.288 | 1.282 | 1.275 | 1.269 | 1.262 |
| 758 | 1.358 | 1.352 | 1.346 | 1.341 | 1.334 | 1.329 | 1.322 | 1.316 | 1.310 | 1.304 | 1.298 | 1.291 | 1.285 | 1.279 | 1.272 | 1.265 |
| 760 | 1.362 | 1.356 | 1.350 | 1.344 | 1.338 | 1.332 | 1.326 | 1.320 | 1.314 | 1.307 | 1.301 | 1.295 | 1.288 | 1.282 | 1.276 | 1.269 |
| 762 | 1.366 | 1.360 | 1.354 | 1.348 | 1.342 | 1.336 | 1.330 | 1.323 | 1.317 | 1.311 | 1.304 | 1.298 | 1.292 | 1.285 | 1.279 | 1.272 |
| 764 | 1.369 | 1.363 | 1.357 | 1.351 | 1.345 | 1.339 | 1.333 | 1.327 | 1.321 | 1.314 | 1.308 | 1.302 | 1.295 | 1.289 | 1.282 | 1.276 |
| 766 | 1.373 | 1.367 | 1.361 | 1.355 | 1.349 | 1.343 | 1.337 | 1.331 | 1.324 | 1.318 | 1.312 | 1.305 | 1.299 | 1.292 | 1.286 | 1.279 |
| 768 | 1.377 | 1.371 | 1.365 | 1.359 | 1.353 | 1.346 | 1.340 | 1.334 | 1.328 | 1.322 | 1.315 | 1.309 | 1.302 | 1.296 | 1.289 | 1.283 |
| 770 | 1.380 | 1.374 | 1.368 | 1.362 | 1.356 | 1.350 | 1.344 | 1.338 | 1.331 | 1.325 | 1.319 | 1.312 | 1.306 | 1.299 | 1.293 | 1.286 |

# **Nitrogen.** Weight, in mgms., of Nitrogen in 1 cc. of Gas measured saturated with Water Vapour at the given temperature and pressure. (Gattermann).

| mm. | 10°   | 11°   | 12°   | 13°   | 14°   | 15°   | 16°   | 17°   | 18°   | 19°   | 20°   | 21°   | 22°   | 23°   | 24°   | 25°   |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 720 | 1.128 | 1.123 | 1.118 | 1.113 | 1.108 | 1.103 | 1.098 | 1.093 | 1.088 | 1.082 | 1.077 | 1.072 | 1.066 | 1.061 | 1.055 | 1.050 |
| 722 | 1.132 | 1.126 | 1.122 | 1.117 | 1.111 | 1.106 | 1.101 | 1.096 | 1.091 | 1.086 | 1.080 | 1.075 | 1.069 | 1.064 | 1.058 | 1.053 |
| 724 | 1.135 | 1.130 | 1.125 | 1.120 | 1.114 | 1.109 | 1.104 | 1.099 | 1.094 | 1.089 | 1.083 | 1.078 | 1.073 | 1.067 | 1.061 | 1.056 |
| 726 | 1.138 | 1.133 | 1.128 | 1.123 | 1.118 | 1.113 | 1.107 | 1.102 | 1.097 | 1.092 | 1.086 | 1.081 | 1.076 | 1.070 | 1.064 | 1.059 |
| 728 | 1.141 | 1.136 | 1.131 | 1.126 | 1.121 | 1.116 | 1.111 | 1.105 | 1.100 | 1.095 | 1.089 | 1.084 | 1.079 | 1.073 | 1.067 | 1.062 |
| 730 | 1.144 | 1.139 | 1.134 | 1.129 | 1.124 | 1.119 | 1.114 | 1.108 | 1.103 | 1.098 | 1.092 | 1.087 | 1.082 | 1.076 | 1.070 | 1.065 |
| 732 | 1.147 | 1.142 | 1.137 | 1.132 | 1.127 | 1.122 | 1.117 | 1.111 | 1.106 | 1.101 | 1.095 | 1.090 | 1.085 | 1.079 | 1.073 | 1.068 |
| 734 | 1.151 | 1.145 | 1.140 | 1.135 | 1.130 | 1.125 | 1.120 | 1.115 | 1.109 | 1.104 | 1.099 | 1.093 | 1.088 | 1.082 | 1.076 | 1.071 |
| 736 | 1.154 | 1.149 | 1.144 | 1.139 | 1.133 | 1.128 | 1.123 | 1.118 | 1.112 | 1.107 | 1.102 | 1.096 | 1.091 | 1.085 | 1.080 | 1.074 |
| 738 | 1.157 | 1.152 | 1.147 | 1.142 | 1.136 | 1.131 | 1.126 | 1.121 | 1.116 | 1.110 | 1.105 | 1.099 | 1.094 | 1.088 | 1.083 | 1.077 |
| 740 | 1.160 | 1.155 | 1.150 | 1.145 | 1.140 | 1.134 | 1.129 | 1.124 | 1.119 | 1.113 | 1.108 | 1.102 | 1.097 | 1.091 | 1.086 | 1.080 |
| 742 | 1.163 | 1.158 | 1.153 | 1.148 | 1.143 | 1.137 | 1.132 | 1.127 | 1.122 | 1.116 | 1.111 | 1.105 | 1.100 | 1.094 | 1.089 | 1.083 |
| 744 | 1.166 | 1.161 | 1.156 | 1.151 | 1.146 | 1.141 | 1.135 | 1.130 | 1.125 | 1.119 | 1.114 | 1.108 | 1.103 | 1.097 | 1.092 | 1.086 |
| 746 | 1.170 | 1.164 | 1.159 | 1.154 | 1.149 | 1.144 | 1.138 | 1.133 | 1.128 | 1.122 | 1.117 | 1.111 | 1.106 | 1.100 | 1.095 | 1.089 |
| 748 | 1.173 | 1.168 | 1.163 | 1.157 | 1.152 | 1.147 | 1.142 | 1.136 | 1.131 | 1.126 | 1.120 | 1.115 | 1.109 | 1.103 | 1.098 | 1.092 |
| 750 | 1.176 | 1.171 | 1.166 | 1.161 | 1.155 | 1.150 | 1.145 | 1.139 | 1.134 | 1.129 | 1.123 | 1.118 | 1.112 | 1.106 | 1.101 | 1.095 |
| 752 | 1.179 | 1.174 | 1.169 | 1.164 | 1.158 | 1.153 | 1.148 | 1.143 | 1.137 | 1.132 | 1.126 | 1.121 | 1.115 | 1.109 | 1.104 | 1.098 |
| 754 | 1.182 | 1.177 | 1.172 | 1.167 | 1.161 | 1.156 | 1.151 | 1.146 | 1.140 | 1.135 | 1.129 | 1.124 | 1.118 | 1.112 | 1.107 | 1.101 |
| 756 | 1.186 | 1.180 | 1.175 | 1.170 | 1.165 | 1.159 | 1.154 | 1.149 | 1.143 | 1.138 | 1.132 | 1.127 | 1.121 | 1.115 | 1.110 | 1.104 |
| 758 | 1.189 | 1.183 | 1.178 | 1.173 | 1.168 | 1.162 | 1.157 | 1.152 | 1.146 | 1.141 | 1.135 | 1.130 | 1.124 | 1.119 | 1.113 | 1.107 |
| 760 | 1.192 | 1.187 | 1.181 | 1.176 | 1.171 | 1.166 | 1.160 | 1.155 | 1.149 | 1.144 | 1.138 | 1.133 | 1.127 | 1.122 | 1.116 | 1.110 |
| 762 | 1.195 | 1.190 | 1.185 | 1.179 | 1.174 | 1.169 | 1.163 | 1.158 | 1.153 | 1.147 | 1.141 | 1.136 | 1.130 | 1.125 | 1.119 | 1.113 |
| 764 | 1.198 | 1.193 | 1.188 | 1.182 | 1.177 | 1.172 | 1.166 | 1.161 | 1.156 | 1.150 | 1.145 | 1.139 | 1.133 | 1.128 | 1.122 | 1.116 |
| 766 | 1.201 | 1.196 | 1.191 | 1.186 | 1.180 | 1.175 | 1.170 | 1.164 | 1.159 | 1.153 | 1.148 | 1.142 | 1.136 | 1.131 | 1.125 | 1.119 |
| 768 | 1.205 | 1.199 | 1.194 | 1.189 | 1.183 | 1.178 | 1.173 | 1.167 | 1.162 | 1.156 | 1.151 | 1.145 | 1.139 | 1.134 | 1.128 | 1.122 |
| 770 | 1.208 | 1.202 | 1.197 | 1.192 | 1.187 | 1.181 | 1.176 | 1.170 | 1.165 | 1.159 | 1.154 | 1.148 | 1.143 | 1.137 | 1.131 | 1.125 |



# SOLUBILITIES.

## I. Gases in Liquids.

The amount of gas dissolved (absorbed) by a liquid is directly proportional to the pressure (Dalton's or Henry's law), provided that no chemical combination occurs between the solute and the solvent. In the case of a gas mixture, the gases dissolve in proportion to their respective partial pressures, i.e. the pressure each gas would exert respectively if it occupied the entire volume available instead of a part corresponding to its percentage by volume.

The *Absorption Coefficient*,  $\alpha$ , of a gas gives the volume of gas (calculated to N.T.P.) absorbed by 1 volume of liquid at a certain temperature when the partial pressure of the gas is 760 mm.

The symbol,  $q$ , represents grams of gas dissolved by 100 grams of solvent when the total pressure (= partial pressure of gas + partial pressure of vapour of solvent) is 760 mm.

$\alpha^1$  represents vols. of gas absorbed by 1 vol. liquid at temperature when total pressure is 760 mm.

**Solubility of the Constituents of Dry Air (free from  $\text{CO}_2$  and  $\text{NH}_3$ ) in Water.** (Winkler, 1904).

| 1 litre water contains<br>cc. gas (N.T.P.) |              |                     |                                 | 1 litre water contains<br>cc. gas (N.T.P.) |              |                     |                                 |
|--|--------------|---------------------|---------------------------------|--|--------------|---------------------|---------------------------------|
| $^{\circ}\text{C.}$                        | $\text{O}_2$ | $\text{N}_2$ , etc. | % $\text{O}_2$ in<br>dissd. gas | $^{\circ}\text{C.}$                        | $\text{O}_2$ | $\text{N}_2$ , etc. | % $\text{O}_2$ in<br>dissd. gas |
| 0  | 10.19        | 18.99               | 34.91                           | 16   | 6.89         | 13.25               | 34.21                           |
| 1  | 9.91         | 18.51               | 34.87                           | 17   | 6.75         | 13.00               | 34.17                           |
| 2  | 9.64         | 18.05               | 34.82                           | 18   | 6.61         | 12.77               | 34.12                           |
| 3  | 9.39         | 17.60               | 34.78                           | 19   | 6.48         | 12.54               | 34.08                           |
| 4  | 9.14         | 17.18               | 34.74                           | 20   | 6.36         | 12.32               | 34.03                           |
| 5  | 8.91         | 16.77               | 34.69                           | 21   | 6.23         | 12.11               | 33.99                           |
| 6  | 8.68         | 16.38               | 34.65                           | 22   | 6.11         | 11.90               | 33.95                           |
| 7  | 8.47         | 16.00               | 34.60                           | 23   | 6.00         | 11.69               | 33.90                           |
| 8  | 8.26         | 15.64               | 34.56                           | 24   | 5.89         | 11.49               | 33.86                           |
| 9  | 8.06         | 15.30               | 34.52                           | 25   | 5.78         | 11.30               | 33.82                           |
| 10   | 7.87         | 14.97               | 34.47                           | 26   | 5.67         | 11.12               | 33.77                           |
| 11   | 7.69         | 14.65               | 34.43                           | 27   | 5.56         | 10.94               | 33.73                           |
| 12   | 7.52         | 14.35               | 34.38                           | 28   | 5.46         | 10.75               | 33.68                           |
| 13   | 7.35         | 14.06               | 34.34                           | 29   | 5.36         | 10.56               | 33.64                           |
| 14   | 7.19         | 13.78               | 34.30                           | 30   | 5.26         | 10.38               | 33.60                           |
| 15   | 7.04         | 13.51               | 34.25                           |  |              |                     |                                 |

# Solubility of Atmospheric Oxygen in Water. (T. Carlson, 1913).

| °C. | cc. per lit. | °C. | cc. per lit. | °C. | cc. per lit. |
|-----|--------------|-----|--------------|-----|--------------|
| 0   | 10.26        | 10  | 8.02         | 20  | 6.55         |
| 5   | 9.02         | 15  | 7.21         | 25  | 6.00         |

## Solubilities, $\alpha$ , of Gases in Water.

| °C | (Bunsen)<br>Air. | (Raoult, 1874)<br>NH <sub>3</sub> . | (Geffcken, 1904).<br>N <sub>2</sub> O. | (Winkler, 1901).<br>NO. | (Winkler, 1901).<br>CO. | (Winkler, 1901).<br>OH <sub>4</sub> . | (Winkler, 1901).<br>C <sub>2</sub> H <sub>6</sub> .<br>(Winkler,<br>unpublished, 1912).<br>C <sub>2</sub> H <sub>4</sub> . |       |
|----|------------------|-------------------------------------|--|-------------------------|-------------------------|---------------------------------------|--|-------|
| 0  | 0.02471          | 1305                                | —                                      | 0.07381                 | 0.03537                 | 0.05563                               | 0.09814  | 0.226 |
| 1  | 406              | 1225                                | —                                      | 171                     | 3455                    | 5401                                  | 9476   | .219  |
| 2  | 345              | 1165                                | —                                      | 0.06981                 | 3375                    | 5244                                  | 9093   | .211  |
| 3  | 287              | 1107                                | —                                      | 801                     | 3297                    | 5093                                  | 8725   | .204  |
| 4  | 237              | 1058                                | —                                      | 628                     | 3233                    | 4946                                  | 8372   | .197  |
| 5  | 179              | 1024                                | 1.0480                                 | 461                     | 3149                    | 4805                                  | 8033   | .191  |
| 6  | .128             | 1002                                | 1.0140                                 | 300                     | 3078                    | 4669                                  | 7709   | .184  |
| 7  | 090              | 980.2                               | 0.9800                                 | 144                     | 3009                    | 4539                                  | 7400   | .178  |
| 8  | 034              | 959.5                               | .9459                                  | 0.05994                 | 2943                    | 4413                                  | 7106   | .173  |
| 9  | 0.01992          | 937.5                               | .9118                                  | 849                     | 2878                    | 4292                                  | 6826   | .167  |
| 10 | 953              | 915.5                               | .8778                                  | 709                     | 2816                    | 4177                                  | 6561   | .162  |
| 11 | 916              | 892.1                               | .8518                                  | 575                     | 2757                    | 4072                                  | 6328   | .157  |
| 12 | 882              | 870.1                               | .8218                                  | 453                     | 2701                    | 3970                                  | 6106   | .152  |
| 13 | 851              | 848.1                               | .7937                                  | 343                     | 2646                    | 3872                                  | 5894   | .148  |
| 14 | 822              | 826.1                               | .7658                                  | 241                     | 2593                    | 3779                                  | 5694   | .143  |
| 15 | 795              | 806.7                               | .7378                                  | 147                     | 2543                    | 3690                                  | 5504   | .139  |
| 16 | 771              | 787.4                               | .7162                                  | 056                     | 2494                    | 3606                                  | 5326   | .136  |
| 17 | 750              | 768.0                               | .6944                                  | 0.04967                 | 2448                    | 3525                                  | 5159   | .132  |
| 18 | 732              | 748.8                               | .6727                                  | 880                     | 2402                    | 3448                                  | 5003   | .129  |
| 19 | 717              | 730.8                               | .6510                                  | 793                     | 2360                    | 3376                                  | 4858   | .125  |
| 20 | 701              | 715.4                               | .6294                                  | 706                     | 2319                    | 3308                                  | 4724   | .122  |
| 21 | —                | 694.7                               | .6123                                  | —                       | 2281                    | 3243                                  | 4589   | .119  |
| 22 | —                | 678.3                               | .5954                                  | —                       | 2244                    | 3180                                  | 4459   | .116  |
| 23 | —                | 665.6                               | .5783                                  | —                       | 2208                    | 3119                                  | 4335   | .114  |
| 24 | —                | 653.0                               | .5614                                  | —                       | 2174                    | 3061                                  | 4217   | .111  |
| 25 | —                | 640.5                               | .5443                                  | 323                     | 2142                    | 3006                                  | 4104   | .108  |



# Solubility of Hydrogen in Water. (Winkler, 1891.)

| °C. | $\alpha$ | °C. | $\alpha$ | °C. | $\alpha$ |
|-----|----------|-----|----------|-----|----------|
| 0   | 0.02148  | 11  | 0.01940  | 30  | 0.019699 |
| 1   | 126      | 12  | 925      | 35  | 666      |
| 2   | 105      | 13  | 911      | 40  | 644      |
| 3   | 084      | 14  | 897      | 45  | 624      |
| 4   | 064      | 15  | 883      | 50  | 608      |
| 5   | 044      | 16  | 869      | 60  | 600      |
| 6   | 025      | 17  | 856      | 70  | 600      |
| 7   | 007      | 18  | 844      | 80  | 600      |
| 8   | 0.01989  | 19  | 831      | 90  | 600      |
| 9   | 972      | 20  | 819      | 100 | 600      |
| 10  | 955      | 25  | 754      |     |          |

# Solubility of Oxygen and Nitrogen in Water. (Fox, 1909).

| °C. | Oxygen.  | Nitrogen. | °C. | Oxygen.  | Nitrogen. |
|-----|----------|-----------|-----|----------|-----------|
|     | $\alpha$ | $\alpha$  |     | $\alpha$ | $\alpha$  |
| 0   | 0.04924  | 0.02300   | 26  | 0.02842  | 0.01423   |
| 1   | 4794     | 2250      | 27  | 2794     | 1404      |
| 2   | 4665     | 2202      | 28  | 2751     | 1387      |
| 3   | 4545     | 2155      | 29  | 2708     | 1371      |
| 4   | 4431     | 2109      | 30  | 2665     | 1355      |
| 5   | 4321     | 2064      | 31  | 2627     | 1339      |
| 6   | 4215     | 2020      | 32  | 2590     | 1323      |
| 7   | 4115     | 0.01977   | 33  | 2554     | 1308      |
| 8   | 4019     | 1935      | 34  | 2519     | 1293      |
| 9   | 0.03928  | 1894      | 35  | 2485     | 1279      |
| 10  | 3837     | 1854      | 36  | 2452     | 1265      |
| 11  | 3751     | 1816      | 37  | 2420     | 1252      |
| 12  | 3675     | 1780      | 38  | 2389     | 1239      |
| 13  | 3598     | 1746      | 39  | 2359     | 1227      |
| 14  | 3526     | 1714      | 40  | 2330     | 1215      |
| 15  | 3455     | 1684      | 41  | 2302     | 1204      |
| 16  | 3388     | 1656      | 42  | 2275     | 1192      |
| 17  | 3321     | 1629      | 43  | 2249     | 1180      |
| 18  | 3258     | 1603      | 44  | 2224     | 1168      |
| 19  | 3201     | 1578      | 45  | 2200     | 1157      |
| 20  | 3144     | 1554      | 46  | 2177     | 1146      |
| 21  | 3091     | 1529      | 47  | 2155     | 1135      |
| 22  | 3038     | 1506      | 48  | 2134     | 1124      |
| 23  | 0.02986  | 1484      | 49  | 2114     | 1113      |
| 24  | 2938     | 1463      | 50  | 2095     | 1102      |
| 25  | 2890     | 1443      |     |          |           |

# Solubilities, $\alpha$ , of Rare Gases in Water. (von Antropoff, 1919).

| °C. | Helium. | Neon.  | Argon. | Krypton. | Xenon. | Radium<br>Emanation |
|-----|---------|--------|--------|----------|--------|---------------------|
| 0   | 0.0097  | 0.0114 | 0.0578 | 0.1105   | 0.242  | 0.510               |
| 10  | .0099   | .0118  | .0452  | .0810    | .174   | .326                |
| 20  | .0100   | .0147  | .0374  | .0626    | .123   | .222                |
| 30  | .0101   | .0155  | .0326  | .0511    | .098   | .162                |
| 40  | .0103   | .0217  | .0286  | .0433    | .082   | .126                |
| 50  | .0108   | .0322  | .0257  | .0383    | .073   | .100                |
| 60  | —       | —      | —      | .0357    | —      | .085                |

## Solubility of Ammonia in Water. (Roscoe and Dittmar, 1859).

| °C. | q    | °C. | q    | °C. | q    | °C. | q    | °C. | q    | °C. | q    |
|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|
| 0   | 87.5 | 10  | 67.9 | 20  | 52.6 | 30  | 40.3 | 40  | 30.7 | 50  | 22.9 |
| 2   | 83.3 | 12  | 64.5 | 22  | 49.9 | 32  | 38.2 | 42  | 29.0 | 52  | 21.4 |
| 4   | 79.2 | 14  | 61.2 | 24  | 47.4 | 34  | 36.2 | 44  | 27.5 | 54  | 20.0 |
| 6   | 75.1 | 16  | 58.2 | 26  | 44.9 | 36  | 34.3 | 46  | 25.9 | 56  | 18.6 |
| 8   | 71.3 | 18  | 55.4 | 28  | 42.6 | 38  | 32.4 | 48  | 24.4 |     |      |

## Solubility of Carbon Dioxide in Water. (Bohr and Bock, 1891).

| °C. | $\alpha$ | q      | °C. | $\alpha$ | q      | °C. | $\alpha$ | q      |
|-----|----------|--------|-----|----------|--------|-----|----------|--------|
| 0   | 1.713    | 0.3347 | 12  | 1.117    | 0.2166 | 24  | 0.781    | 0.1494 |
| 1   | 1.646    | 214    | 13  | 1.083    | 099    | 25  | 0.759    | 450    |
| 2   | 1.584    | 091    | 14  | 1.050    | 033    | 26  | 0.738    | 407    |
| 3   | 1.527    | 0.2979 | 15  | 1.019    | 0.1971 | 27  | 0.718    | 367    |
| 4   | 1.473    | 872    | 16  | 0.985    | 904    | 28  | 0.699    | 328    |
| 5   | 1.424    | 774    | 17  | 0.956    | 845    | 29  | 0.682    | 293    |
| 6   | 1.377    | 681    | 18  | 0.928    | 789    | 30  | 0.665    | 250    |
| 7   | 1.331    | 590    | 19  | 0.902    | 736    | 35  | 0.592    | 106    |
| 8   | 1.282    | 494    | 20  | 0.878    | 689    | 40  | 0.530    | 0.0974 |
| 9   | 1.237    | 404    | 21  | 0.854    | 641    | 45  | 0.479    | 862    |
| 10  | 1.194    | 319    | 22  | 0.829    | 591    | 50  | 0.436    | 762    |
| 11  | 1.154    | 240    | 23  | 0.804    | 541    | 60  | 0.359    | 577    |

# Solubility of Chlorine in Water. (Winkler, 1907).

( $\alpha_1$  for total pressure of 760 mm.)

| °C. | $\alpha_1$ | q      | °C. | $\alpha_1$ | q      | °C. | $\alpha_1$ | q      |
|-----|------------|--------|-----|------------|--------|-----|------------|--------|
| 10  | 3.095      | 0.9969 | 20  | 2.260      | 0.7291 | 30  | 1.769      | 0.5722 |
| 11  | 2.996      | 0.9652 | 21  | 2.200      | 0.7098 | 35  | 1.575      | 0.5103 |
| 12  | 2.900      | 0.9344 | 22  | 2.143      | 0.6916 | 40  | 1.414      | 0.4589 |
| 13  | 2.808      | 0.9048 | 23  | 2.087      | 0.6737 | 45  | 1.300      | 0.4227 |
| 14  | 2.720      | 0.8766 | 24  | 2.035      | 0.6570 | 50  | 1.204      | 0.3927 |
| 15  | 2.635      | 0.8493 | 25  | 1.985      | 0.6411 | 60  | 1.006      | 0.3294 |
| 16  | 2.553      | 0.8230 | 26  | 1.937      | 0.6257 | 70  | 0.848      | 0.2792 |
| 17  | 2.474      | 0.7977 | 27  | 1.891      | 0.6110 | 80  | 0.672      | 0.2226 |
| 18  | 2.399      | 0.7736 | 28  | 1.848      | 0.5973 | 90  | 0.380      | 0.1268 |
| 19  | 2.328      | 0.7508 | 29  | 1.808      | 0.5845 | 100 | 0.000      | 0.0000 |

# Solubility of Hydrobromic Acid in Water.

(Roozeboom, 1885).

( $\alpha_1$  for total pressure of 760 mm.)

| °C. | $\alpha_1$ | q     | °C. | $\alpha_1$ | q     | °C. | $\alpha_1$ | q     |
|-----|------------|-------|-----|------------|-------|-----|------------|-------|
| -25 | -          | 255.0 | -5  | 630.0      | 228.0 | 50  | 468.6      | 171.2 |
| -20 | -          | 247.3 | 0   | 611.6      | 221.2 | 75  | 406.7      | 150.5 |
| -12 | -          | 239.0 | +10 | 581.4      | 210.3 | 100 | 344.6      | 130.0 |
| -10 | 644.5      | 233.5 | 25  | 582.1      | 193.0 |     |            |       |

# Solubility of Hydrochloric Acid in Water.

(Roscoe and Dittmar, 1859).

( $\alpha_1$  for total pressure of 760 mm.)

| °C. | $\alpha_1$ | q    | °C. | $\alpha_1$ | q    | °C. | $\alpha_1$ | q    |
|-----|------------|------|-----|------------|------|-----|------------|------|
| 0   | 506.5      | 82.5 | 22  | 435.0      | 71.0 | 44  | -          | 61.8 |
| 2   | 499.8      | 81.4 | 24  | 428.7      | 70.0 | 46  | -          | 61.1 |
| 4   | 493.7      | 80.4 | 26  | 423.0      | 69.1 | 48  | -          | 60.3 |
| 6   | 486.9      | 79.3 | 28  | 417.2      | 68.2 | 50  | 361.6      | 59.6 |
| 8   | 480.8      | 78.3 | 30  | 411.5      | 67.3 | 52  | -          | 58.9 |
| 10  | 473.9      | 77.2 | 32  | -          | 66.5 | 54  | -          | 58.2 |
| 12  | 467.7      | 76.2 | 34  | -          | 65.7 | 56  | -          | 57.5 |
| 14  | 461.5      | 75.2 | 36  | -          | 64.9 | 58  | -          | 56.8 |
| 16  | 455.2      | 74.2 | 38  | -          | 64.1 | 60  | 338.7      | 56.1 |
| 18  | 448.3      | 73.1 | 40  | 385.7      | 63.3 |     |            |      |
| 20  | 442.0      | 72.1 | 42  | -          | 62.6 |     |            |      |

# Solubility of Hydrogen Sulphide in Water. (Winkler, 1907).

| °C. | $\alpha$ | °C. | $\alpha$ | °C. | $\alpha$ | °C. | $\alpha$ |
|-----|----------|-----|----------|-----|----------|-----|----------|
| 0   | 4.621    | 8   | 3.578    | 16  | 2.834    | 24  | 2.312    |
| 1   | 4.475    | 9   | 3.468    | 17  | 2.759    | 25  | 2.257    |
| 2   | 4.333    | 10  | 3.362    | 18  | 2.687    | 26  | 2.204    |
| 3   | 4.196    | 11  | 3.265    | 19  | 2.619    | 27  | 2.153    |
| 4   | 4.063    | 12  | 3.172    | 20  | 2.554    | 28  | 2.105    |
| 5   | 3.935    | 13  | 3.082    | 21  | 2.491    | 29  | 2.058    |
| 6   | 3.811    | 14  | 2.996    | 22  | 2.429    | 30  | 2.014    |
| 7   | 3.692    | 15  | 2.913    | 23  | 2.370    |     |          |

# Solubility of Sulphur Dioxide in Water. (Schönfeld, 1855).

| °C. | $\alpha$ | °C. | $\alpha$ | °C. | $\alpha$ | °C. | $\alpha$ |
|-----|----------|-----|----------|-----|----------|-----|----------|
| 0   | 79.789   | 11  | 54.655   | 22  | 36.617   | 33  | 24.244   |
| 1   | 77.210   | 12  | 52.723   | 23  | 35.302   | 34  | 23.347   |
| 2   | 74.691   | 13  | 50.849   | 24  | 34.026   | 35  | 22.489   |
| 3   | 72.230   | 14  | 49.033   | 25  | 32.786   | 36  | 21.668   |
| 4   | 69.828   | 15  | 47.276   | 26  | 31.584   | 37  | 20.886   |
| 5   | 67.485   | 16  | 45.578   | 27  | 30.422   | 38  | 20.141   |
| 6   | 65.200   | 17  | 43.939   | 28  | 29.314   | 39  | 19.435   |
| 7   | 62.973   | 18  | 42.360   | 29  | 28.210   | 40  | 18.766   |
| 8   | 60.805   | 19  | 40.838   | 30  | 27.161   |     |          |
| 9   | 58.697   | 20  | 39.374   | 31  | 26.151   |     |          |
| 10  | 56.647   | 21  | 37.970   | 32  | 25.178   |     |          |

# Solubility of Oxygen in Alcohol. (Timofejeff, 1890).

| °C. | $\alpha$ | °C. | $\alpha$ | °C. | $\alpha$ | °C. | $\alpha$ |
|-----|----------|-----|----------|-----|----------|-----|----------|
| 0   | 0.23370  | 7   | 0.22863  | 14  | 0.22389  | 21  | 0.21946  |
| 1   | 296      | 8   | 793      | 15  | 324      | 22  | 886      |
| 2   | 222      | 9   | 724      | 16  | 259      | 23  | 826      |
| 3   | 149      | 10  | 656      | 17  | 195      | 24  | 767      |
| 4   | 077      | 11  | 588      | 18  | 132      |     |          |
| 5   | 005      | 12  | 521      | 19  | 069      |     |          |
| 6   | 0.22934  | 13  | 455      | 20  | 007      |     |          |

Solubilities,  $\alpha$ , of Gases in Alcohol. (Carius,\* Bunsen).

| $\circ$ C. | Hydrogen. | Nitrogen. | N <sub>2</sub> O | NO      | CO <sub>2</sub> | CH <sub>4</sub> | C <sub>2</sub> H <sub>4</sub> | H <sub>2</sub> S | SO <sub>2</sub> * |
|------------|-----------|-----------|------------------|---------|-----------------|-----------------|-------------------------------|------------------|-------------------|
| 0          | 0.06925   | 0.12634   | 4.1780           | 0.31606 | 4.3295          | 0.52259         | 3.5950                        | 17.891           | 328.62            |
| 1          | 910       | 593       | 4.1088           | 1262    | 4.2368          | 1973            | 3.5379                        | 17.242           | 311.98            |
| 2          | 886       | 553       | 4.0409           | 0.30928 | 4.1466          | 1691            | 3.4823                        | 16.606           | 295.97            |
| 3          | 881       | 514       | 3.9741           | 604     | 4.0589          | 1412            | 3.4280                        | 15.983           | 280.58            |
| 4          | 867       | 476       | 3.9085           | 290     | 3.9736          | 1135            | 3.3750                        | 15.373           | 265.81            |
| 5          | 853       | 440       | 3.8442           | 0.29985 | 3.8908          | 0861            | 3.3234                        | 14.776           | 251.67            |
| 6          | 839       | 405       | 3.7811           | 690     | 3.8105          | 0590            | 3.2732                        | 14.193           | 238.16            |
| 7          | 826       | 371       | 3.7192           | 405     | 3.7327          | 0322            | 3.2243                        | 13.623           | 225.25            |
| 8          | 813       | 338       | 3.6585           | 130     | 3.6573          | 0057            | 3.1768                        | 13.066           | 212.98            |
| 9          | 799       | 306       | 3.5990           | 0.28865 | 3.5844          | 0.49795         | 3.1307                        | 12.523           | 201.33            |
| 10         | 786       | 276       | 3.5403           | 609     | 3.5140          | 9535            | 3.0859                        | 11.992           | 190.31            |
| 11         | 774       | 247       | 3.4838           | 363     | 3.4461          | 9278            | 3.0425                        | 11.475           | 179.91            |
| 12         | 761       | 219       | 3.4279           | 127     | 3.3807          | 9024            | 3.0005                        | 10.971           | 170.13            |
| 13         | 749       | 192       | 3.3734           | 0.27901 | 3.3178          | 8773            | 2.9598                        | 10.480           | 160.98            |
| 14         | 737       | 166       | 3.3200           | 685     | 3.2573          | 8525            | 2.9205                        | 10.003           | 152.45            |
| 15         | 725       | 142       | 3.2678           | 478     | 3.1993          | 8280            | 2.8825                        | 9.539            | 144.55            |
| 16         | 713       | 119       | 3.2169           | 281     | 3.1438          | 8037            | 2.8459                        | 9.088            | 137.27            |
| 17         | 701       | 097       | 3.1672           | 094     | 3.0908          | 7798            | 2.8107                        | 8.650            | 130.61            |
| 18         | 690       | 076       | 3.1187           | 0.26917 | 3.0402          | 7561            | 2.7768                        | 8.225            | 124.58            |
| 19         | 679       | 056       | 3.0714           | 750     | 2.9921          | 7327            | 2.7443                        | 7.814            | 119.17            |
| 20         | 668       | 038       | 3.0253           | 592     | 2.9465          | 7096            | 2.7131                        | 7.415            | 114.48            |
| 21         | 657       | 021       | 2.9805           | 444     | 2.9034          | 6867            | 2.6833                        | 7.030            | 110.22            |
| 22         | 646       | 005       | 2.9368           | 306     | 2.8628          | 6642            | 2.6549                        | 6.659            | 106.68            |
| 23         | 636       | 0.11990   | 2.8944           | 178     | 2.8247          | 6419            | 2.6279                        | 6.300            | 103.77            |
| 24         | 626       | 976       | 2.8532           | 060     | 2.7890          | 6199            | 2.6022                        | 5.955            | 101.47            |
| 25         | 616       | 964       | 2.8133           | 0.25951 | 2.7558          | 5982            | 2.5778                        | 5.623            | 99.81             |

## II. Solids in Liquids.

The solubility of solids depends mainly on the temperature, but is also influenced by the nature of a substance (its source, treatment, degree of hydration, etc.) and to a small extent by the pressure.

In the following tables  $W$  = grms. of substance in 100 grms. water,  $S$  = grms. of substance in 100 grms. solution.

The volume of a solution is generally smaller than the sum of the volumes of the constituents (*e.g.* alcohol and water), but exceptions are known (*e.g.* alcohol and carbon disulphide).

Unless otherwise stated, the solvent is water.

### Solubility of Aluminium Sulphate. (Poggiale, 1843).

| °C. | $Al_2(SO_4)_3$<br>W. | $Al_2(SO_4)_3 \cdot 18H_2O$<br>W. | °C. | $Al_2(SO_4)_3$<br>W. | $Al_2(SO_4)_3 \cdot 18H_2O$<br>W. |
|-----|----------------------|-----------------------------------|-----|----------------------|-----------------------------------|
| 0   | 31.3                 | 86.85                             | 60  | 59.1                 | 262.6                             |
| 10  | 33.5                 | 95.8                              | 70  | 66.23                | 348.2                             |
| 20  | 36.15                | 107.35                            | 80  | 73.1                 | 467.3                             |
| 30  | 40.36                | 127.6                             | 90  | 80.8                 | 678.8                             |
| 40  | 45.73                | 167.6                             | 100 | 89.11                | 1132.0                            |
| 50  | 52.13                | 201.4                             |     |                      |                                   |

### Solubility of Ammonia Alum. (Poggiale, 1843).

| °C. | Anhydrous.<br>W. | Crystals<br>with $24H_2O$<br>W. | °C. | Anhydrous.<br>W. | Crystals<br>with $24H_2O$<br>W. |
|-----|------------------|---------------------------------|-----|------------------|---------------------------------|
| 0   | 2.10             | 3.90                            | 25  | 9.19             | 19.19                           |
| 5   | 3.50             | 6.91                            | 30  | 10.94            | 22.01                           |
| 10  | 4.99             | 9.52                            | 40  | 14.88            | 30.92                           |
| 15  | 6.25             | 12.66                           | 50  | 20.10            | 44.10                           |
| 20  | 7.74             | 15.13                           | 60  | 26.70            | 66.65                           |

### Solubility of Ammonium Nitrate.

(Muller and Kaufmann, 1903).

| °C.  | W. ( $NH_4NO_3$ ) | °C. | W. ( $NH_4NO_3$ ) |
|------|-------------------|-----|-------------------|
| 0    | 118.3             | 40  | 297               |
| 12.2 | 153.4             | 50  | 344               |
| 20.2 | 192.4             | 60  | 421               |
| 25.0 | 214.2             | 70  | 499               |
| 30.0 | 241.8             | 80  | 580               |
| 32.1 | 256.9             | 90  | 740               |
| 35.0 | 265.8             | 100 | 871               |

## Solubility of Ammonium Chloride (Mulder).

| °C. | NH <sub>4</sub> Cl.<br>W. | °C. | NH <sub>4</sub> Cl.<br>W. | °C.    | NH <sub>4</sub> Cl.<br>W. |
|-----|---------------------------|-----|---------------------------|--------|---------------------------|
| 0   | 29.7                      | 39  | 45.3                      | 78     | 64.5                      |
| 1   | 30.0                      | 40  | 45.8                      | 79     | 65.1                      |
| 2   | 30.3                      | 41  | 46.2                      | 80     | 65.6                      |
| 3   | 30.6                      | 42  | 46.7                      | 81     | 66.2                      |
| 4   | 31.0                      | 43  | 47.1                      | 82     | 66.7                      |
| 5   | 31.4                      | 44  | 47.6                      | 83     | 67.3                      |
| 6   | 31.8                      | 45  | 48.0                      | 84     | 67.8                      |
| 7   | 32.2                      | 46  | 48.5                      | 85     | 68.4                      |
| 8   | 32.6                      | 47  | 49.0                      | 86     | 69.0                      |
| 9   | 33.0                      | 48  | 49.5                      | 87     | 69.6                      |
| 10  | 33.3                      | 49  | 49.9                      | 88     | 70.2                      |
| 11  | 33.7                      | 50  | 50.4                      | 89     | 70.7                      |
| 12  | 34.1                      | 51  | 50.9                      | 90     | 71.3                      |
| 13  | 34.5                      | 52  | 51.3                      | 91     | 71.9                      |
| 14  | 34.8                      | 53  | 51.8                      | 92     | 72.5                      |
| 15  | 35.2                      | 54  | 52.3                      | 93     | 73.1                      |
| 16  | 35.6                      | 55  | 52.8                      | 94     | 73.7                      |
| 17  | 36.0                      | 56  | 53.2                      | 95     | 74.3                      |
| 18  | 36.4                      | 57  | 53.7                      | 96     | 74.9                      |
| 19  | 36.8                      | 58  | 54.2                      | 97     | 75.5                      |
| 20  | 37.2                      | 59  | 54.7                      | 98     | 76.1                      |
| 21  | 37.6                      | 60  | 55.2                      | 99     | 76.7                      |
| 22  | 38.0                      | 61  | 55.7                      | 100    | 77.3                      |
| 23  | 38.4                      | 62  | 56.2                      | 101    | 78.0                      |
| 24  | 38.8                      | 63  | 56.7                      | 102    | 78.6                      |
| 25  | 39.3                      | 64  | 57.2                      | 103    | 79.2                      |
| 26  | 39.7                      | 65  | 57.7                      | 104    | 79.9                      |
| 27  | 40.1                      | 66  | 58.2                      | 105    | 80.5                      |
| 28  | 40.5                      | 67  | 58.7                      | 106    | 81.2                      |
| 29  | 40.9                      | 68  | 59.2                      | 107    | 81.8                      |
| 30  | 41.4                      | 69  | 59.7                      | 108    | 82.5                      |
| 31  | 41.8                      | 70  | 60.2                      | 109    | 82.1                      |
| 32  | 42.2                      | 71  | 60.7                      | 110    | 83.8                      |
| 33  | 42.7                      | 72  | 61.2                      | 111    | 84.4                      |
| 34  | 43.1                      | 73  | 61.7                      | 112    | 85.1                      |
| 35  | 43.6                      | 74  | 62.2                      | 113    | 85.7                      |
| 36  | 44.0                      | 75  | 62.8                      | 114    | 86.4                      |
| 37  | 44.4                      | 76  | 63.4                      | 115    | 87.1                      |
| 38  | 44.9                      | 77  | 63.9                      | 115.65 | 87.3                      |

## Solubility of Ammonium Sulphate. (Mulder).

| °C. | $(\text{NH}_4)_2\text{SO}_4$<br>W. | °C. | $(\text{NH}_4)_2\text{SO}_4$<br>W. | °C.   | $(\text{NH}_4)_2\text{SO}_4$<br>W. |
|-----|------------------------------------|-----|------------------------------------|-------|------------------------------------|
| 0   | 70.6                               | 37  | 80.1                               | 74    | 93.1                               |
| 1   | 70.9                               | 38  | 80.4                               | 75    | 93.4                               |
| 2   | 71.1                               | 39  | 80.7                               | 76    | 93.8                               |
| 3   | 71.4                               | 40  | 81.0                               | 77    | 94.2                               |
| 4   | 71.6                               | 41  | 81.3                               | 78    | 94.5                               |
| 5   | 71.8                               | 42  | 81.7                               | 79    | 94.9                               |
| 6   | 72.1                               | 43  | 82.0                               | 80    | 95.3                               |
| 7   | 72.3                               | 44  | 82.3                               | 81    | 95.6                               |
| 8   | 72.5                               | 45  | 82.7                               | 82    | 96.0                               |
| 9   | 72.8                               | 46  | 83.0                               | 83    | 96.4                               |
| 10  | 73.0                               | 47  | 83.3                               | 84    | 96.8                               |
| 11  | 73.2                               | 48  | 83.7                               | 85    | 97.2                               |
| 12  | 73.5                               | 49  | 84.0                               | 86    | 97.6                               |
| 13  | 73.7                               | 50  | 84.4                               | 87    | 98.0                               |
| 14  | 74.0                               | 51  | 84.7                               | 88    | 98.4                               |
| 15  | 74.2                               | 52  | 85.1                               | 89    | 98.8                               |
| 16  | 74.4                               | 53  | 85.5                               | 90    | 99.2                               |
| 17  | 74.7                               | 54  | 85.8                               | 91    | 99.6                               |
| 18  | 74.9                               | 55  | 86.2                               | 92    | 100.0                              |
| 19  | 75.1                               | 56  | 86.6                               | 93    | 100.4                              |
| 20  | 75.4                               | 57  | 86.9                               | 94    | 100.8                              |
| 21  | 75.7                               | 58  | 87.3                               | 95    | 101.2                              |
| 22  | 75.9                               | 59  | 87.7                               | 96    | 101.6                              |
| 23  | 76.2                               | 60  | 88.0                               | 97    | 102.1                              |
| 24  | 76.4                               | 61  | 88.4                               | 98    | 102.5                              |
| 25  | 76.7                               | 62  | 88.7                               | 99    | 102.9                              |
| 26  | 76.9                               | 63  | 89.1                               | 100   | 103.3                              |
| 27  | 77.2                               | 64  | 89.5                               | 101   | 103.8                              |
| 28  | 77.5                               | 65  | 89.9                               | 102   | 104.2                              |
| 29  | 77.8                               | 66  | 90.2                               | 103   | 104.6                              |
| 30  | 78.0                               | 67  | 90.6                               | 104   | 105.1                              |
| 31  | 78.3                               | 68  | 90.9                               | 105   | 105.5                              |
| 32  | 78.6                               | 69  | 91.3                               | 106   | 106.0                              |
| 33  | 78.9                               | 70  | 91.6                               | 107   | 106.5                              |
| 34  | 79.2                               | 71  | 92.0                               | 108   | 107.0                              |
| 35  | 79.5                               | 72  | 92.4                               | 108.9 | 107.5                              |
| 36  | 79.8                               | 73  | 92.7                               |       |                                    |



## Solubility of Ammonium Thiocyanate.

|       | W.    |                       |
|-------|-------|-----------------------|
| 0°C.  | 128.1 | (NH <sub>4</sub> )CNS |
| 20°C. | 162.2 | „                     |

## Solubility of Arsenious Oxide.

| Crystallised modification<br>(Bruner and St. Tolloczko 1903). |   | Amorphous modification.<br>(Winkler).                  |       |
|---|---|--|-------|
| °C.   | Grms. As <sub>2</sub> O <sub>3</sub> in 100 cc. soln. | Grms. As <sub>2</sub> O <sub>3</sub> in 100 cc. water. |       |
| 2   | 1.201   | Ord. temp.   | 3.7   |
| 15  | 1.657   | B.Pt.  | 11.86 |
| 25  | 2.038   |  |       |
| 39.8  | 2.930   |  |       |

## Solubility of Barium Chlorate.

(Trautz and Ausschütz, 1906).

| °C. | Ba(ClO <sub>3</sub> ) <sub>2</sub> . |       | °C. | Ba(ClO <sub>3</sub> ) <sub>2</sub> . |        |
|-----|--------------------------------------|-------|-----|--------------------------------------|--------|
|     | S.                                   | W.    |     | S.                                   | W.     |
| 0   | 16.90                                | 20.40 | 50  | 36.69                                | 57.95  |
| 10  | 21.23                                | 26.94 | 60  | 40.05                                | 66.80  |
| 20  | 25.26                                | 33.80 | 70  | 43.04                                | 75.56  |
| 25  | 27.53                                | 37.99 | 80  | 45.90                                | 84.84  |
| 30  | 29.43                                | 41.70 | 90  | 48.70                                | 94.93  |
| 40  | 33.16                                | 49.61 | 100 | 51.17                                | 104.80 |

## Solubility of Barium Hydroxide.

(Rosenstiehl 1870).

| °C. | Ba(OH) <sub>2</sub> |  | °C.  | Ba(OH) <sub>2</sub> |  |
|-----|---------------------|--|------|---------------------|--|
|     | W.                  | Ba(OH) <sub>2</sub> .8H <sub>2</sub> O<br>W. |      | W.                  | Ba(OH) <sub>2</sub> .8H <sub>2</sub> O<br>W. |
| 0   | 1.5                 | -  | 45   | 9.12                | -  |
| 5   | 1.75                | -  | 50   | 11.75               | -  |
| 10  | 2.23                | 4.69   | 55   | 14.71               | -  |
| 15  | 2.89                | -  | 60   | 18.76               | 48.08  |
| 20  | 3.48                | 7.43   | 65   | 24.67               | -  |
| 25  | 4.19                | -  | 70   | 31.9                | -  |
| 30  | 5.0                 | -  | 75   | 56.85               | -  |
| 35  | 6.17                | -  | 78.5 | 94.74               | -  |
| 40  | 7.36                | 16.42  | 80   | 90.77               | 38.46  |

## Solubility of Barium Chloride. (Mulder).

| °C. | BaCl <sub>2</sub><br>W. | °C. | BaCl <sub>2</sub><br>W. | °C.   | BaCl <sub>2</sub><br>W. |
|-----|-------------------------|-----|-------------------------|-------|-------------------------|
| 0   | 30.9                    | 36  | 39.7                    | 72    | 50.0                    |
| 1   | 31.2                    | 37  | 40.0                    | 73    | 50.3                    |
| 2   | 31.5                    | 38  | 40.2                    | 74    | 50.6                    |
| 3   | 31.7                    | 39  | 40.5                    | 75    | 50.9                    |
| 4   | 31.9                    | 40  | 40.7                    | 76    | 51.2                    |
| 5   | 32.2                    | 41  | 41.0                    | 77    | 51.5                    |
| 6   | 32.4                    | 42  | 41.3                    | 78    | 51.8                    |
| 7   | 32.6                    | 43  | 41.6                    | 79    | 52.1                    |
| 8   | 32.8                    | 44  | 41.9                    | 80    | 52.4                    |
| 9   | 33.1                    | 45  | 42.2                    | 81    | 52.7                    |
| 10  | 33.3                    | 46  | 42.5                    | 82    | 53.0                    |
| 11  | 33.5                    | 47  | 42.7                    | 83    | 53.3                    |
| 12  | 33.8                    | 48  | 43.0                    | 84    | 53.6                    |
| 13  | 34.0                    | 49  | 43.3                    | 85    | 54.0                    |
| 14  | 34.2                    | 50  | 43.6                    | 86    | 54.3                    |
| 15  | 34.5                    | 51  | 43.9                    | 87    | 54.6                    |
| 16  | 34.7                    | 52  | 44.2                    | 88    | 55.0                    |
| 17  | 35.0                    | 53  | 44.4                    | 89    | 55.3                    |
| 18  | 35.2                    | 54  | 44.7                    | 90    | 55.6                    |
| 19  | 35.5                    | 55  | 45.0                    | 91    | 55.9                    |
| 20  | 35.7                    | 56  | 45.3                    | 92    | 56.2                    |
| 21  | 36.0                    | 57  | 45.6                    | 93    | 56.6                    |
| 22  | 36.2                    | 58  | 45.9                    | 94    | 56.9                    |
| 23  | 36.5                    | 59  | 46.2                    | 95    | 57.2                    |
| 24  | 36.7                    | 60  | 46.4                    | 96    | 57.6                    |
| 25  | 37.0                    | 61  | 46.7                    | 97    | 57.9                    |
| 26  | 37.2                    | 62  | 47.0                    | 98    | 58.2                    |
| 27  | 37.5                    | 63  | 47.3                    | 99    | 58.5                    |
| 28  | 37.7                    | 64  | 47.6                    | 100   | 58.8                    |
| 29  | 38.0                    | 65  | 47.9                    | 101   | 59.2                    |
| 30  | 38.2                    | 66  | 48.2                    | 102   | 59.5                    |
| 31  | 38.5                    | 67  | 48.5                    | 103   | 59.8                    |
| 32  | 38.7                    | 68  | 48.8                    | 104   | 60.2                    |
| 33  | 39.0                    | 69  | 49.1                    | 104.1 | 60.3                    |
| 34  | 39.2                    | 70  | 49.4                    |       |                         |
| 35  | 39.5                    | 71  | 49.7                    |       |                         |

# Solubility of Benzoic Acid and Salicylic Acid. (Bourgoin, 1878).

| °C. | $\text{C}_6\text{H}_5\text{COOH}$<br>W. | $\text{C}_6\text{H}_4(\text{OH})\text{COOH}$<br>W. | °C. | $\text{C}_6\text{H}_5\text{COOH}$<br>W. | $\text{C}_6\text{H}_4(\text{OH})\text{COOH}$<br>W. |
|-----|---|--|-----|---|--|
| 0   | 0.170                                   | 0.150  | 40  | 0.555                                   | 0.555  |
| 5   | 0.185                                   | 0.165  | 45  | 0.650                                   | 0.665  |
| 10  | 0.210                                   | 0.190  | 50  | 0.775                                   | 0.800  |
| 15  | 0.245                                   | 0.225  | 55  | 0.940                                   | 0.980  |
| 20  | 0.290                                   | 0.270  | 60  | 1.155                                   | 1.225  |
| 25  | 0.345                                   | 0.325  | 65  | 1.430                                   | 1.555  |
| 30  | 0.410                                   | 0.390  | 70  | 1.775                                   | 1.990  |
| 35  | 0.480                                   | 0.465  | 75  | 2.200                                   | 2.550  |

# Solubility of Borax. (Horn and van Wagener, 1903)

| °C. | Anhydrous salt.<br>S. | W.   | °C. | Anhydrous salt.<br>S. | W.   |
|-----|-----------------------|------|-----|-----------------------|------|
| 0   | †1.3                  | †1.3 | *60 | 16.7                  | 20.0 |
| 5   | 1.3                   | 1.3  | 65  | 18.0                  | 21.9 |
| 10  | 1.6                   | 1.6  | 70  | 19.6                  | 24.4 |
| 30  | 3.7                   | 3.9  | 80  | 23.9                  | 31.4 |
| 45  | 7.5                   | 8.1  | 90  | 29.0                  | 40.8 |
| 50  | 9.5                   | 10.5 | 100 | 34.3                  | 52.2 |
| 55  | 12.4                  |      |     |                       |      |

\* Transition point Hydrate 10 aq. + 5 aq.

† These values from Mulder.

## Solubility of Boric Acid. (Nasini and Ageno, 1909).

| °C. | $\text{H}_3\text{BO}_3$<br>S. | $\text{B}_2\text{O}_3$<br>W. | °C.  | $\text{H}_3\text{BO}_3$<br>S. | $\text{B}_2\text{O}_3$<br>W. |
|-----|-------------------------------|------------------------------|------|-------------------------------|------------------------------|
| 0   | 2.52                          | 2.59                         | 55   | 10.34                         | 11.53                        |
| 5   | 2.98                          | 3.08                         | 60   | 11.42                         | 12.90                        |
| 10  | 3.46                          | 3.59                         | 65   | 12.47                         | 14.25                        |
| 15  | 4.03                          | 4.19                         | 70   | 13.60                         | 15.75                        |
| 20  | 4.38                          | 4.79                         | 75   | 14.67                         | 17.20                        |
| 25  | 5.17                          | 5.45                         | 80   | 16.04                         | 19.11                        |
| 30  | 5.89                          | 6.25                         | 85   | 17.45                         | 21.15                        |
| 35  | 6.65                          | 7.12                         | 90   | 18.97                         | 23.30                        |
| 40  | 7.42                          | 8.02                         | 95   | 20.39                         | 25.62                        |
| 45  | 8.41                          | 9.18                         | 99.5 | 21.93                         | 28.10                        |
| 50  | 9.37                          | 10.35                        |      |                               |                              |

## Solubility of Calcium Chloride. (Roozeboom, 1889).

| °C.         | $\text{CaCl}_2$<br>S. | W.    | °C.   | $\text{CaCl}_2$<br>S. | W.    |
|-------------|-----------------------|-------|-------|-----------------------|-------|
| -25         | 33.3                  | 49.9  | 70    | 58.6                  | 141.6 |
| 20          | 34.1                  | 51.8  | 75    | 59.0                  | 143.9 |
| 15          | 34.9                  | 53.6  | 80    | 59.5                  | 146.9 |
| 10          | 35.7                  | 55.6  | 85    | 59.9                  | 149.4 |
| 5           | 36.5                  | 57.5  | 90    | 60.4                  | 152.5 |
| 0           | 37.3                  | 59.5  | 95    | 60.9                  | 155.8 |
| +5          | 38.0                  | 61.3  | 100   | 61.4                  | 159.1 |
| 10          | 39.4                  | 65.0  | 105   | 62.0                  | 163.2 |
| 15          | 40.6                  | 68.4  | 110   | 62.4                  | 166.0 |
| 20          | 42.7                  | 74.5  | 115   | 62.9                  | 169.5 |
| 25          | 46.2                  | 85.9  | 120   | 63.4                  | 173.2 |
| * (i) 29.8  | 50.1                  | 100.4 | 125   | 63.9                  | 177.0 |
| 30          | 50.2                  | 100.8 | 130   | 64.5                  | 181.7 |
| 35          | 51.8                  | 107.5 | 135   | 65.0                  | 185.7 |
| 40          | 53.5                  | 115.3 | 140   | 65.6                  | 190.7 |
| 45          | 56.4                  | 130.4 | 145   | 66.4                  | 197.6 |
| * (ii) 45.3 | 56.6                  | 129.4 | 150   | 67.3                  | 205.8 |
| 50          | 57.0                  | 132.6 | 155   | 68.1                  | 213.5 |
| 55          | 57.4                  | 134.7 | 160   | 69.0                  | 222.6 |
| 60          | 57.8                  | 136.8 | 161.5 | 69.4                  | 226.8 |
| 65          | 58.2                  | 139.3 |       |                       |       |

\* Transition point for (i) Hydrate with 6 aq.+4 aq. (a); (ii) Hydrate with 4 aq.+2 aq.

## Solubility of Calcium Hydroxide. (Maben 1883).

| °C. | CaO<br>W. | °C. | CaO<br>W. | °C. | CaO<br>W. |
|-----|-----------|-----|-----------|-----|-----------|
| 0   | 0.131     | 40  | 0.107     | 80  | 0.073     |
| 10  | 0.129     | 50  | 0.098     | 90  | 0.063     |
| 20  | 0.126     | 60  | 0.088     | 100 | 0.060     |
| 30  | 0.116     | 70  | 0.080     |     |           |

## Solubility of Cane Sugar. (Herzfeld, 1892).

| °C. | Cane sugar. |       | °C. | Cane sugar. |       |
|-----|-------------|-------|-----|-------------|-------|
|     | S.          | W.    |     | S.          | W.    |
| 0   | 64.18       | 179.2 | 28  | 68.37       | 216.3 |
| 1   | 64.31       | 180.3 | 29  | 68.53       | 217.9 |
| 2   | 64.45       | 181.4 | 30  | 68.70       | 219.5 |
| 3   | 64.59       | 182.5 | 31  | 68.87       | 221.3 |
| 4   | 64.73       | 183.6 | 32  | 69.04       | 223.1 |
| 5   | 64.87       | 184.7 | 33  | 69.21       | 224.8 |
| 6   | 65.01       | 185.8 | 34  | 69.38       | 226.6 |
| 7   | 65.15       | 187.0 | 35  | 69.55       | 228.4 |
| 8   | 65.29       | 188.2 | 36  | 69.72       | 230.3 |
| 9   | 65.43       | 189.3 | 37  | 69.89       | 232.3 |
| 10  | 65.58       | 190.5 | 38  | 70.06       | 234.2 |
| 11  | 65.73       | 191.8 | 39  | 70.24       | 236.1 |
| 12  | 65.88       | 193.1 | 40  | 70.42       | 238.1 |
| 13  | 66.03       | 194.4 | 41  | 70.60       | 240.2 |
| 14  | 66.18       | 195.7 | 42  | 70.78       | 242.3 |
| 15  | 66.33       | 197.0 | 43  | 70.96       | 244.4 |
| 16  | 66.48       | 198.4 | 44  | 71.14       | 246.6 |
| 17  | 66.63       | 199.7 | 45  | 71.32       | 248.7 |
| 18  | 66.78       | 201.1 | 46  | 71.50       | 251.0 |
| 19  | 66.93       | 202.5 | 47  | 71.68       | 253.3 |
| 20  | 67.09       | 203.9 | 48  | 71.87       | 255.7 |
| 21  | 67.25       | 205.4 | 49  | 72.06       | 258.0 |
| 22  | 67.41       | 206.9 | 50  | 72.25       | 260.4 |
| 23  | 67.57       | 208.4 | 51  | 72.44       | 262.9 |
| 24  | 67.73       | 209.9 | 52  | 72.63       | 265.5 |
| 25  | 67.89       | 211.4 | 53  | 72.82       | 268.0 |
| 26  | 68.05       | 213.0 | 54  | 73.01       | 270.6 |
| 27  | 68.21       | 214.7 | 55  | 73.20       | 273.1 |

| °C. | Cane sugar. |       | °C. | Cane sugar. |       |
|-----|-------------|-------|-----|-------------|-------|
|     | S.          | W.    |     | S.          | W.    |
| 56  | 73.39       | 276.0 | 79  | 78.14       | 357.6 |
| 57  | 73.58       | 278.8 | 80  | 78.36       | 362.1 |
| 58  | 73.78       | 281.6 | 81  | 78.58       | 367.1 |
| 59  | 73.98       | 284.5 | 82  | 78.80       | 372.0 |
| 60  | 74.18       | 287.3 | 83  | 79.02       | 376.9 |
| 61  | 74.38       | 290.4 | 84  | 79.24       | 381.9 |
| 62  | 74.58       | 293.5 | 85  | 79.46       | 386.8 |
| 63  | 74.78       | 296.7 | 86  | 79.69       | 392.6 |
| 64  | 74.98       | 299.8 | 87  | 79.92       | 398.4 |
| 65  | 75.18       | 302.9 | 88  | 80.15       | 404.2 |
| 66  | 75.38       | 306.4 | 89  | 80.38       | 409.9 |
| 67  | 75.59       | 310.0 | 90  | 80.61       | 415.7 |
| 68  | 75.80       | 313.5 | 91  | 80.84       | 422.3 |
| 69  | 76.01       | 317.0 | 92  | 81.07       | 428.8 |
| 70  | 76.22       | 320.4 | 93  | 81.30       | 435.4 |
| 71  | 76.43       | 324.4 | 94  | 81.53       | 442.0 |
| 72  | 76.64       | 328.3 | 95  | 81.77       | 448.0 |
| 73  | 76.85       | 332.2 | 96  | 82.01       | 456.3 |
| 74  | 77.06       | 336.0 | 97  | 82.25       | 464.0 |
| 75  | 77.27       | 339.9 | 98  | 82.49       | 471.7 |
| 76  | 77.48       | 344.4 | 99  | 82.73       | 479.4 |
| 77  | 77.70       | 348.8 | 100 | 82.97       | 487.2 |
| 78  | 77.92       | 353.2 |     |             |       |

**Solubility of Cobalt Ammonium Sulphate.**  
(Tobler 1855).

| °C. | $\text{CoSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4$<br>W. | °C. | $\text{CoSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4$<br>W. |
|-----|--|-----|--|
| 0   | 8.9  | 40  | 22.3   |
| 10  | 11.6   | 45  | 25   |
| 18  | 15.2   | 50  | 28.7   |
| 23  | 17.1   | 60  | 34.5   |
| 35  | 19.6   | 75  | 43.3   |

## Solubility of Cobalt Sulphate. (Mulder 1864).

| °C. | CoSO <sub>4</sub><br>W. | °C. | CoSO <sub>4</sub><br>W. | °C. | CoSO <sub>4</sub><br>W. |
|-----|-------------------------|-----|-------------------------|-----|-------------------------|
| 0   | 24.6                    | 34  | 42.4                    | 68  | 62.6                    |
| 1   | 25.0                    | 35  | 42.9                    | 69  | 63.2                    |
| 2   | 25.5                    | 36  | 43.5                    | 70  | 63.8                    |
| 3   | 26.0                    | 37  | 44.0                    | 71  | 64.4                    |
| 4   | 26.5                    | 38  | 44.6                    | 72  | 65.0                    |
| 5   | 27.0                    | 39  | 45.2                    | 73  | 65.6                    |
| 6   | 27.5                    | 40  | 45.8                    | 74  | 66.2                    |
| 7   | 28.0                    | 41  | 46.4                    | 75  | 66.8                    |
| 8   | 28.5                    | 42  | 47.0                    | 76  | 67.4                    |
| 9   | 29.0                    | 43  | 47.6                    | 77  | 68.0                    |
| 10  | 29.5                    | 44  | 48.2                    | 78  | 68.6                    |
| 11  | 30.0                    | 45  | 48.8                    | 79  | 69.2                    |
| 12  | 30.5                    | 46  | 49.4                    | 80  | 69.8                    |
| 13  | 31.0                    | 47  | 50.0                    | 81  | 70.4                    |
| 14  | 31.5                    | 48  | 50.6                    | 82  | 71.0                    |
| 15  | 32.0                    | 49  | 51.2                    | 83  | 71.6                    |
| 16  | 32.5                    | 50  | 51.8                    | 84  | 72.2                    |
| 17  | 33.0                    | 51  | 52.4                    | 85  | 72.8                    |
| 18  | 33.5                    | 52  | 53.0                    | 86  | 73.4                    |
| 19  | 34.0                    | 53  | 53.6                    | 87  | 74.0                    |
| 20  | 34.5                    | 54  | 54.2                    | 88  | 74.6                    |
| 21  | 35.1                    | 55  | 54.8                    | 89  | 75.2                    |
| 22  | 35.6                    | 56  | 55.4                    | 90  | 75.9                    |
| 23  | 36.2                    | 57  | 56.0                    | 91  | 76.6                    |
| 24  | 36.8                    | 58  | 56.6                    | 92  | 77.2                    |
| 25  | 37.4                    | 59  | 57.2                    | 93  | 77.9                    |
| 26  | 38.0                    | 60  | 57.8                    | 94  | 78.6                    |
| 27  | 38.5                    | 61  | 58.4                    | 95  | 79.2                    |
| 28  | 39.1                    | 62  | 59.0                    | 96  | 79.9                    |
| 29  | 39.6                    | 63  | 59.6                    | 97  | 80.6                    |
| 30  | 40.2                    | 64  | 60.2                    | 98  | 81.3                    |
| 31  | 40.7                    | 65  | 60.8                    | 99  | 81.9                    |
| 32  | 41.3                    | 66  | 61.4                    | 100 | 82.6                    |
| 33  | 41.8                    | 67  | 62.0                    |     |                         |

## Solubility of Copper Sulphate. (Mulder).

| °C. | CuSO <sub>4</sub><br>W. | °C. | CuSO <sub>4</sub><br>W. | °C. | CuSO <sub>4</sub><br>W. |
|-----|-------------------------|-----|-------------------------|-----|-------------------------|
| 0   | 15.5                    | 35  | 27.5                    | 70  | 45.7                    |
| 1   | 16.3                    | 36  | 27.9                    | 71  | 46.4                    |
| 2   | 16.6                    | 37  | 28.3                    | 72  | 47.2                    |
| 3   | 16.9                    | 38  | 28.7                    | 73  | 47.9                    |
| 4   | 17.2                    | 39  | 29.1                    | 74  | 48.7                    |
| 5   | 17.5                    | 40  | 29.5                    | 75  | 49.5                    |
| 6   | 17.8                    | 41  | 29.9                    | 76  | 50.3                    |
| 7   | 18.1                    | 42  | 30.3                    | 77  | 51.1                    |
| 8   | 18.4                    | 43  | 30.7                    | 78  | 51.9                    |
| 9   | 18.7                    | 44  | 31.1                    | 79  | 52.7                    |
| 10  | 19.1                    | 45  | 31.5                    | 80  | 53.5                    |
| 11  | 19.3                    | 46  | 31.9                    | 81  | 54.3                    |
| 12  | 19.6                    | 47  | 32.3                    | 82  | 55.1                    |
| 13  | 19.9                    | 48  | 32.7                    | 83  | 55.9                    |
| 14  | 20.2                    | 49  | 33.2                    | 84  | 56.8                    |
| 15  | 20.5                    | 50  | 33.6                    | 85  | 57.8                    |
| 16  | 20.8                    | 51  | 34.1                    | 86  | 58.7                    |
| 17  | 21.1                    | 52  | 34.5                    | 87  | 59.7                    |
| 18  | 21.4                    | 53  | 35.0                    | 88  | 60.7                    |
| 19  | 21.7                    | 54  | 35.5                    | 89  | 61.7                    |
| 20  | 22.0                    | 55  | 36.0                    | 90  | 62.7                    |
| 21  | 22.3                    | 56  | 36.6                    | 91  | 63.7                    |
| 22  | 22.6                    | 57  | 37.2                    | 92  | 64.8                    |
| 23  | 23.0                    | 58  | 37.8                    | 93  | 65.8                    |
| 24  | 23.3                    | 59  | 38.4                    | 94  | 66.9                    |
| 25  | 23.7                    | 60  | 39.0                    | 95  | 68.0                    |
| 26  | 24.0                    | 61  | 39.6                    | 96  | 69.1                    |
| 27  | 24.4                    | 62  | 40.2                    | 97  | 70.2                    |
| 28  | 24.7                    | 63  | 40.9                    | 98  | 71.3                    |
| 29  | 25.1                    | 64  | 41.5                    | 99  | 72.4                    |
| 30  | 25.5                    | 65  | 42.2                    | 100 | 73.5                    |
| 31  | 25.9                    | 66  | 42.9                    | 101 | 74.6                    |
| 32  | 26.3                    | 67  | 43.6                    | 102 | 75.7                    |
| 33  | 26.7                    | 68  | 44.3                    | 103 | 76.8                    |
| 34  | 27.1                    | 69  | 45.0                    | 104 | 77.95                   |



## Solubility of Ferrous Ammonium Sulphate.

(Tobler, 1855).

| °C. | $\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4$<br>W. | °C. | $\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4$<br>W. |
|-----|--|-----|--|
| 9   | 12.2   | 45  | 36.2   |
| 12  | 17.5   | 55  | 40.3   |
| 20  | 21.6   | 60  | 44.6   |
| 30  | 28.1   | 65  | 49.8   |
| 36  | 31.8   | 75  | 56.7   |

## Solubility of Ferrous Sulphate. (Fraenkel, 1907).

| °C. | $\text{FeSO}_4$<br>W. S. |       | °C.          | $\text{FeSO}_4$<br>W. S. |       |
|-----|--------------------------|-------|--------------|--------------------------|-------|
| 0   | 15.65                    | 13.53 | 55           | 53.15                    | 34.70 |
| 5   | 18.07                    | 15.32 | * (i) 56.17  | 54.60                    | 35.32 |
| 10  | 20.51                    | 17.02 | 60           | 54.94                    | 35.46 |
| 15  | 23.48                    | 19.01 | * (ii) 64.00 | 55.36                    | 35.63 |
| 20  | 26.60                    | 21.01 | 65           | 54.64                    | 35.33 |
| 25  | 29.81                    | 22.96 | 70           | 50.99                    | 33.77 |
| 30  | 32.94                    | 24.78 | 75           | 47.47                    | 32.19 |
| 35  | 36.40                    | 26.69 | 80           | 43.90                    | 30.51 |
| 40  | 40.15                    | 28.65 | 85           | 40.58                    | 28.86 |
| 45  | 44.14                    | 30.62 | 90           | 37.35                    | 27.19 |
| 50  | 48.43                    | 32.63 |              |                          |       |

\*Transition points: (i) Hydrate with 7 aq.+4 aq.; (ii) Hydrate with 4 aq.+1 aq.

## Solubility of Lead Chloride. (Lichty, 1903.)

| °C. | Grams.<br>$\text{PbCl}_2$ in<br>100 grams.<br>water. | Grams.<br>$\text{PbCl}_2$ in<br>100 cc.<br>solution. | °C. | Grams.<br>$\text{PbCl}_2$ in<br>100 grams.<br>water. | Grams.<br>$\text{PbCl}_2$ in<br>100 cc.<br>solution. |
|-----|--|--|-----|--|--|
| 0   | 0.6728   | 0.6728   | 55  | 1.8263   | 1.8019   |
| 15  | 0.9090   | 0.9070   | 65  | 2.1265   | 2.0810   |
| 25  | 1.0842   | 1.0786   | 80  | 2.6224   | 2.5420   |
| 35  | 1.3244   | 1.315  | 95  | 3.1654   | 3.0358   |
| 45  | 1.5673   | 1.5498   | 100 | 3.342  | 3.208  |

## Solubility of Lead Nitrate. (Mulder).

| °C. | Pb(NO <sub>3</sub> ) <sub>2</sub><br>W. | °C. | Pb(NO <sub>3</sub> ) <sub>2</sub><br>W. | °C.   | Pb(NO <sub>3</sub> ) <sub>2</sub><br>W. |
|-----|---|-----|---|-------|---|
| 0   | 36.5                                    | 36  | 65.9                                    | 72    | 99.7                                    |
| 1   | 37.4                                    | 37  | 66.7                                    | 73    | 100.7                                   |
| 2   | 38.3                                    | 38  | 67.6                                    | 74    | 101.7                                   |
| 3   | 39.1                                    | 39  | 68.5                                    | 75    | 102.6                                   |
| 4   | 39.8                                    | 40  | 69.4                                    | 76    | 103.6                                   |
| 5   | 40.5                                    | 41  | 70.3                                    | 77    | 104.6                                   |
| 6   | 41.2                                    | 42  | 71.2                                    | 78    | 105.6                                   |
| 7   | 42.0                                    | 43  | 72.1                                    | 79    | 106.6                                   |
| 8   | 42.8                                    | 44  | 73.0                                    | 80    | 107.6                                   |
| 9   | 43.6                                    | 45  | 74.0                                    | 81    | 108.6                                   |
| 10  | 44.4                                    | 46  | 74.9                                    | 82    | 109.6                                   |
| 11  | 45.2                                    | 47  | 75.9                                    | 83    | 110.6                                   |
| 12  | 46.0                                    | 48  | 76.8                                    | 84    | 111.5                                   |
| 13  | 46.8                                    | 49  | 77.7                                    | 85    | 112.5                                   |
| 14  | 47.5                                    | 50  | 78.7                                    | 86    | 113.5                                   |
| 15  | 48.3                                    | 51  | 79.6                                    | 87    | 114.5                                   |
| 16  | 49.1                                    | 52  | 80.5                                    | 88    | 115.4                                   |
| 17  | 49.9                                    | 53  | 81.5                                    | 89    | 116.4                                   |
| 18  | 50.7                                    | 54  | 82.4                                    | 90    | 117.4                                   |
| 19  | 51.5                                    | 55  | 83.3                                    | 91    | 118.4                                   |
| 20  | 52.3                                    | 56  | 84.3                                    | 92    | 119.4                                   |
| 21  | 53.1                                    | 57  | 85.2                                    | 93    | 120.3                                   |
| 22  | 53.9                                    | 58  | 86.1                                    | 94    | 121.3                                   |
| 23  | 54.7                                    | 59  | 87.1                                    | 95    | 122.3                                   |
| 24  | 55.6                                    | 60  | 88.0                                    | 96    | 123.2                                   |
| 25  | 56.4                                    | 61  | 89.0                                    | 97    | 124.2                                   |
| 26  | 57.3                                    | 62  | 90.0                                    | 98    | 125.2                                   |
| 27  | 58.1                                    | 63  | 90.9                                    | 99    | 126.1                                   |
| 28  | 59.0                                    | 64  | 91.9                                    | 100   | 127.0                                   |
| 29  | 59.8                                    | 65  | 92.8                                    | 101   | 128.0                                   |
| 30  | 60.7                                    | 66  | 93.8                                    | 102   | 128.9                                   |
| 31  | 61.6                                    | 67  | 94.8                                    | 103   | 129.9                                   |
| 32  | 62.4                                    | 68  | 95.7                                    | 104   | 130.9                                   |
| 33  | 63.3                                    | 69  | 96.7                                    | 104.7 | 131.5                                   |
| 34  | 64.1                                    | 70  | 97.7                                    |       |   |
| 35  | 65.0                                    | 71  | 98.7                                    |       |   |

## Solubility of Magnesium Sulphate.

| °C.      | MgSO <sub>4</sub> . |      | °C.       | MgSO <sub>4</sub> . |      |
|----------|---------------------|------|-----------|---------------------|------|
|          | S.                  | W.   |           | S.                  | W.   |
| 0        | 21.0                | 26.6 | 50        | 33.5                | 50.4 |
| *(i) 1.8 | 21.1                | 26.7 | 55        | 34.3                | 52.2 |
| 5        | 22.3                | 28.7 | 60        | 35.5                | 55.0 |
| 10       | 23.6                | 30.9 | 65        | 36.4                | 57.4 |
| 15       | 24.9                | 33.3 | *(iii) 68 | 37.0                | 58.7 |
| 20       | 26.2                | 36.0 | 70        | 37.3                | 59.5 |
| 25       | 66.8                | 36.6 | 75        | 37.9                | 61.0 |
| 30       | 29.0                | 40.8 | 80        | 38.6                | 62.9 |
| 35       | 30.1                | 43.1 | 85        | 40.3                | 67.5 |
| 40       | 31.3                | 45.6 | 90        | 40.4                | 67.8 |
| 45       | 32.4                | 47.9 | 95        | 40.5                | 68.1 |
| *(ii) 48 | 33.0                | 49.3 | 99.4      | 40.6                | 68.4 |

\* Transition points: Hydrate with (i) 12 aq. + 7 aq. rhomb.; (ii) 7 aq. rhomb. + 6 aq.; (iii) 6 aq. + 1 aq.

Solubility of Manganese Sulphate.  
(Cottrell, 1900).

| °C.      | MnSO <sub>4</sub> . |       | °C. | MnSO <sub>4</sub> . |       |
|----------|---------------------|-------|-----|---------------------|-------|
|          | S.                  | W.    |     | S.                  | W.    |
| 0        | 34.7                | 53.16 | 50  | 37.3                | 59.48 |
| 5        | 36.0                | 56.28 | 55  | 36.6                | 57.81 |
| *(i) 9   | 37.2                | 59.23 | 60  | 35.9                | 55.98 |
| 10       | 37.3                | 59.41 | 65  | 35.0                | 53.98 |
| 15       | 37.9                | 60.05 | 70  | 34.2                | 51.98 |
| 20       | 38.6                | 62.88 | 75  | 33.2                | 49.63 |
| 25       | 39.3                | 64.75 | 80  | 32.0                | 47.11 |
| *(ii) 27 | 39.8                | 66.13 | 85  | 30.7                | 44.28 |
| 30       | 39.4                | 65.03 | 90  | 29.1                | 40.95 |
| 35       | 38.9                | 62.04 | 95  | 27.1                | 37.23 |
| 40       | 38.4                | 62.28 | 100 | 24.9                | 33.16 |
| 45       | 37.8                | 60.77 |     |                     |       |

\* Transition points: (i) Hydrate with 7 aq. + 5 aq.; (ii) Hydrate with 5 aq. + 1 aq.

## Solubility of Mercuric Chloride. (Poggiale).

| °C. | HgCl <sub>2</sub><br>W. | °C. | HgCl <sub>2</sub><br>W. | °C. | HgCl <sub>2</sub><br>W. |
|-----|-------------------------|-----|-------------------------|-----|-------------------------|
| 0   | 5.73                    | 40  | 9.62                    | 80  | 24.30                   |
| 10  | 6.57                    | 50  | 11.34                   | 90  | 37.05                   |
| 20  | 7.39                    | 60  | 13.86                   | 100 | 53.96                   |
| 30  | 8.43                    | 70  | 17.29                   |     |                         |

Solubility of Naphthionic Acid and  
*ortho*-Naphthionic Acid. (Dolinski, 1905).

| °C. | <i>p</i> -Acid.<br>W. | <i>o</i> -Acid.<br>W. | °C. | <i>p</i> -Acid.<br>W. | <i>o</i> -Acid.<br>W. |
|-----|-----------------------|-----------------------|-----|-----------------------|-----------------------|
| 0   | 0.027                 | 0.24                  | 60  | 0.075                 | 1.01                  |
| 10  | 0.029                 | 0.32                  | 70  | 0.097                 | 1.37                  |
| 20  | 0.031                 | 0.41                  | 80  | 0.130                 | 1.80                  |
| 30  | 0.037                 | 0.52                  | 90  | 0.175                 | 2.40                  |
| 40  | 0.048                 | 0.65                  | 100 | 0.223                 | 3.19                  |
| 50  | 0.059                 | 0.81                  |     |                       |                       |

## Solubility of Nickel Chloride. (Etard, 1894).

| °C. | NiCl <sub>2</sub> . |      | °C. | NiCl <sub>2</sub> . |      |
|-----|---------------------|------|-----|---------------------|------|
|     | S.                  | W.   |     | S.                  | W.   |
| 0   | 36.0                | 56.3 | 50  | 43.2                | 76.1 |
| 5   | 36.8                | 58.2 | 55  | 44.1                | 78.9 |
| 10  | 37.5                | 60.0 | 60  | 44.8                | 81.2 |
| 15  | 38.2                | 61.8 | 65  | 45.5                | 83.5 |
| 20  | 39.0                | 63.9 | 70  | 46.2                | 85.9 |
| 25  | 39.7                | 65.8 | *75 | 46.5                | 86.9 |
| 30  | 40.5                | 68.1 | 80  | 46.5                | 86.9 |
| 35  | 41.1                | 69.8 | 85  | 46.6                | 87.3 |
| 40  | 41.9                | 72.1 | 90  | 46.7                | 87.6 |
| 45  | 42.6                | 74.2 | 95  | 46.8                | 88.0 |

\* Transition point: Hydrate with 4 aq. + 2 aq. There is another at 36.2°, hydrate with 6 aq. + 4 aq.

## Solubility of Nickel Ammonium Sulphate. (Tobler 1855).

| °C. | $\text{NiSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4$<br>W. | °C. | $\text{NiSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4$<br>W. |
|-----|--|-----|--|
| 3.5 | 1.8  | 40  | 11.5   |
| 10  | 3.2  | 50  | 14.4   |
| 14  | 5.8  | 59  | 16.7   |
| 16  | 5.9  | 68  | 18.8   |
| 20  | 8.3  | 85  | 28.6   |

## Solubility of Nickel Sulphate. (Steele and Johnson, 1904).

| °C.        | $\text{NiSO}_4$<br>W.      S. |       | °C.         | $\text{NiSO}_4$<br>W.      S. |       |
|------------|-------------------------------|-------|-------------|-------------------------------|-------|
| 0          | 27.22                         | 21.40 | * (ii) 53.3 | 52.67                         | 34.50 |
| 5          | 29.52                         | 22.75 | 55          | 53.24                         | 34.74 |
| 10         | 31.84                         | 24.12 | 60          | 54.84                         | 35.45 |
| 15         | 34.19                         | 25.50 | 65          | 58.15                         | 36.64 |
| 20         | 36.91                         | 26.93 | 70          | 59.44                         | 37.30 |
| 25         | 39.67                         | 28.35 | 75          | 61.18                         | 37.96 |
| 30         | 42.47                         | 29.80 | 80          | 63.17                         | 38.70 |
| * (i) 31.5 | 43.28                         | 30.20 | 85          | 65.59                         | 39.81 |
| 35         | 43.86                         | 30.78 | 90          | 68.21                         | 40.65 |
| 40         | 46.59                         | 31.57 | 95          | 71.72                         | 42.04 |
| 45         | 48.09                         | 32.45 | 99          | 76.71                         | 43.40 |
| 50         | 50.15                         | 33.40 |             |                               |       |

\* Transition points: (i) Hydrate with 7 aq. + 6 aq. (blue); (ii) Hydrate with 6 aq. (blue) + 6 aq. (green).

## Solubility of Oxalic Acid. (Alluard, 1869; Miczynski, 1886; Henry, 1884; Foote and Andrews, 1905).

| °C. | Anhydrous acid.<br>W.      S. |       | °C. | Anhydrous acid.<br>W.      S. |       |
|-----|-------------------------------|-------|-----|-------------------------------|-------|
| 0   | 3.45                          | 3.33  | 40  | 21.15                         | 17.46 |
| 10  | 5.55                          | 5.26  | 50  | 31.53                         | 23.97 |
| 20  | 8.78                          | 8.07  | 60  | 45.55                         | 31.37 |
| 25  | 11.36                         | 10.21 | 70  | 63.82                         | 38.95 |
| 30  | 13.77                         | 11.91 |     |                               |       |

## Solubilities of the Platinichlorides.

| Platinichlorides.              | Crookes.    |              | Bunsen and Kirchhoff. |              |
|--------------------------------|-------------|--------------|-----------------------|--------------|
|                                | 15°C.<br>W. | 100°C.<br>W. | 20°C.<br>W.           | 100°C.<br>W. |
| $(\text{NH}_4)_2\text{PtCl}_6$ | 0.67        | 1.25         | -                     | -            |
| $\text{K}_2\text{PtCl}_6$      | 0.926       | 5.26         | 1.12                  | 5.18         |
| $\text{Cs}_2\text{PtCl}_6$     | 0.076       | 0.383        | 0.079                 | 0.377        |
| $\text{Rb}_2\text{PtCl}_6$     | 0.135       | 0.637        | 0.141                 | 0.634        |
| $\text{Ti}_2\text{PtCl}_6$     | 0.0064      | 0.051        | -                     | -            |

## Solubility of Potash Alum. (Berkeley, 1904).

| °C. | Anhydrous salt. |      | °C. | Anhydrous salt. |       |
|-----|-----------------|------|-----|-----------------|-------|
|     | W.              | S.   |     | W.              | S.    |
| 0   | 2.90            | 2.83 | 31  | 8.75            | 8.04  |
| 1   | 3.06            | 2.97 | 32  | 9.08            | 8.32  |
| 2   | 3.17            | 3.08 | 33  | 9.41            | 8.60  |
| 3   | 3.28            | 3.18 | 34  | 9.75            | 8.88  |
| 4   | 3.37            | 3.26 | 35  | 10.06           | 9.14  |
| 5   | 3.50            | 3.38 | 36  | 10.43           | 9.44  |
| 6   | 3.65            | 3.52 | 37  | 10.79           | 9.73  |
| 7   | 3.78            | 3.64 | 38  | 11.18           | 10.05 |
| 8   | 3.92            | 3.77 | 39  | 11.56           | 10.36 |
| 9   | 4.05            | 3.85 | 40  | 11.94           | 10.66 |
| 10  | 4.21            | 4.04 | 41  | 12.37           | 11.00 |
| 11  | 4.37            | 4.04 | 42  | 12.78           | 11.33 |
| 12  | 4.53            | 4.33 | 43  | 13.19           | 11.65 |
| 13  | 4.67            | 4.46 | 44  | 13.63           | 11.99 |
| 14  | 4.84            | 4.61 | 45  | 14.12           | 12.37 |
| 15  | 4.97            | 4.74 | 46  | 14.64           | 12.77 |
| 16  | 5.15            | 4.89 | 47  | 15.15           | 13.15 |
| 17  | 5.34            | 5.06 | 48  | 15.70           | 13.56 |
| 18  | 5.50            | 5.21 | 49  | 16.29           | 14.00 |
| 19  | 5.68            | 5.37 | 50  | 16.89           | 14.46 |
| 20  | 5.90            | 5.57 | 51  | 17.59           | 14.96 |
| 21  | 6.09            | 5.74 | 52  | 18.29           | 15.46 |
| 22  | 6.30            | 5.92 | 53  | 18.99           | 15.96 |
| 23  | 6.53            | 6.12 | 54  | 19.75           | 16.40 |
| 24  | 6.75            | 6.32 | 55  | 20.50           | 17.01 |
| 25  | 7.01            | 6.55 | 56  | 21.24           | 17.52 |
| 26  | 7.25            | 6.76 | 57  | 22.05           | 18.05 |
| 27  | 7.53            | 7.00 | 58  | 22.87           | 18.61 |
| 28  | 7.75            | 7.19 | 59  | 23.74           | 19.27 |
| 29  | 8.09            | 7.48 | 60  | 24.62           | 19.75 |
| 30  | 8.40            | 7.74 |     |                 |       |

## Solubility of Potassium Acetate. (Osann).

|         | W.  |                      |
|---------|-----|----------------------|
| 2°C.    | 188 | CH <sub>3</sub> COOK |
| 13.9°C. | 229 | "                    |
| 62°C.   | 492 | "                    |

Solubility of Potassium Antimonyl Tartrate  
(Tartar Emetic). (Brandes).

| °C. | 2K(SbO)C <sub>4</sub> H <sub>4</sub> O <sub>6</sub> + H <sub>2</sub> O<br>W. | °C. | 2K(SbO)C <sub>4</sub> H <sub>4</sub> O <sub>6</sub> + H <sub>2</sub> O<br>W. |
|-----|--|-----|--|
| 8.7 | 5.26   | 50  | 18.18  |
| 21  | 7.94   | 75  | 31.25  |
| 31  | 12.20  | 100 | 35.71  |

## Solubility of Potassium Bitartrate. (Babo).

| °C. | KHC <sub>4</sub> H <sub>4</sub> O <sub>6</sub><br>W. | °C. | KHC <sub>4</sub> H <sub>4</sub> O <sub>6</sub><br>W. |
|-----|--|-----|--|
| 0   | 0.370  | 40  | 1.461  |
| 15  | 0.411  | 50  | 1.954  |
| 25  | 0.845  | 80  | 4.166  |
| 30  | 1.024  | 100 | 6.100  |

## Solubility of Potassium Bromide. (Kremers).

| °C. | KBr<br>W. | °C. | KBr.<br>W. |
|-----|-----------|-----|------------|
| 0   | 53.48     | 60  | 84.74      |
| 20  | 64.60     | 80  | 93.46      |
| 40  | 74.62     | 100 | 102.04     |

## Solubility of Potassium Carbonate. (Mulder).

| °C. | K <sub>2</sub> CO <sub>3</sub><br>W. | °C. | K <sub>2</sub> CO <sub>3</sub><br>W. | °C. | K <sub>2</sub> CO <sub>3</sub><br>W. |
|-----|--------------------------------------|-----|--------------------------------------|-----|--------------------------------------|
| 0   | 89.4                                 | 46  | 119                                  | 92  | 149                                  |
| 1   | 94                                   | 47  | 120                                  | 93  | 150                                  |
| 2   | 97                                   | 48  | 120                                  | 94  | 151                                  |
| 3   | 100                                  | 49  | 121                                  | 95  | 151                                  |
| 4   | 102                                  | 50  | 121                                  | 96  | 152                                  |
| 5   | 104                                  | 51  | 122                                  | 97  | 153                                  |
| 6   | 105                                  | 52  | 122                                  | 98  | 154                                  |
| 7   | 106                                  | 53  | 123                                  | 99  | 155                                  |
| 8   | 107                                  | 54  | 124                                  | 100 | 156                                  |
| 9   | 108                                  | 55  | 124                                  | 101 | 157                                  |
| 10  | 109                                  | 56  | 125                                  | 102 | 158                                  |
| 11  | 109                                  | 57  | 125                                  | 103 | 159                                  |
| 12  | 109                                  | 58  | 126                                  | 104 | 160                                  |
| 13  | 110                                  | 59  | 127                                  | 105 | 161                                  |
| 14  | 110                                  | 60  | 127                                  | 106 | 162                                  |
| 15  | 110                                  | 61  | 128                                  | 107 | 163                                  |
| 16  | 111                                  | 62  | 128                                  | 108 | 164                                  |
| 17  | 111                                  | 63  | 129                                  | 109 | 166                                  |
| 18  | 111                                  | 64  | 130                                  | 110 | 167                                  |
| 19  | 111                                  | 65  | 130                                  | 111 | 168                                  |
| 20  | 112                                  | 66  | 131                                  | 112 | 169                                  |
| 21  | 112                                  | 67  | 132                                  | 113 | 171                                  |
| 22  | 112                                  | 68  | 132                                  | 114 | 172                                  |
| 23  | 112                                  | 69  | 133                                  | 115 | 173                                  |
| 24  | 112                                  | 70  | 133                                  | 116 | 175                                  |
| 25  | 113                                  | 71  | 134                                  | 117 | 176                                  |
| 26  | 113                                  | 72  | 135                                  | 118 | 178                                  |
| 27  | 113                                  | 73  | 135                                  | 119 | 179                                  |
| 28  | 113                                  | 74  | 136                                  | 120 | 181                                  |
| 29  | 114                                  | 75  | 137                                  | 121 | 182                                  |
| 30  | 114                                  | 76  | 137                                  | 122 | 184                                  |
| 31  | 114                                  | 77  | 138                                  | 123 | 185                                  |
| 32  | 114                                  | 78  | 139                                  | 124 | 187                                  |
| 33  | 115                                  | 79  | 139                                  | 125 | 188                                  |
| 34  | 115                                  | 80  | 140                                  | 126 | 190                                  |
| 35  | 115                                  | 81  | 141                                  | 127 | 191                                  |
| 36  | 115                                  | 82  | 141                                  | 128 | 193                                  |
| 37  | 116                                  | 83  | 142                                  | 129 | 195                                  |
| 38  | 116                                  | 84  | 143                                  | 130 | 196                                  |
| 39  | 116                                  | 85  | 144                                  | 131 | 198                                  |
| 40  | 117                                  | 86  | 144                                  | 132 | 200                                  |
| 41  | 117                                  | 87  | 145                                  | 133 | 201                                  |
| 42  | 117                                  | 88  | 146                                  | 134 | 203                                  |
| 43  | 118                                  | 89  | 147                                  | 135 | 205                                  |
| 44  | 118                                  | 90  | 147                                  |     |                                      |
| 45  | 119                                  | 91  | 148                                  |     |                                      |



## Solubility of Potassium Chlorate and Potassium Perchlorate.

| (Gay Lussac.) |                         | (Tilden and Shenstone 1880.) |                         | (Muir.) |                         |
|---------------|-------------------------|------------------------------|-------------------------|---------|-------------------------|
| °C.           | KClO <sub>3</sub><br>W. | °C.                          | KClO <sub>3</sub><br>W. | °C.     | KClO <sub>4</sub><br>W. |
| 0             | 3.33                    | 0                            | 3.3                     | 0       | 0.71                    |
| 13.32         | 5.60                    | 100                          | 56.5                    | 25      | 1.96                    |
| 15.37         | 6.03                    | 120                          | 73.7                    | 50      | 5.34                    |
| 24.43         | 8.44                    | 136                          | 98.9                    | 100     | 18.7                    |
| 35.02         | 12.05                   | 160                          | 148                     |         |                         |
| 49.08         | 18.96                   | 190                          | 183                     |         |                         |
| 74.98         | 35.40                   |                              |                         |         |                         |
| 104.78        | 60.24                   |                              |                         |         |                         |

## Solubility of Potassium Chloride. (Berkeley, 1904).

| °C.  |       |       | °C.                        |       |       |
|------|-------|-------|----------------------------|-------|-------|
| KCl. |       |       | KCl.                       |       |       |
| W.   | S.    |       | W.                         | S.    |       |
| 0    | 28.13 | 21.95 | 60                         | 45.88 | 31.45 |
| 5    | 29.67 | 22.87 | 65                         | 47.13 | 32.04 |
| 10   | 31.29 | 23.35 | 70                         | 48.38 | 32.61 |
| 15   | 32.90 | 24.75 | 75                         | 49.63 | 33.17 |
| 20   | 34.51 | 25.66 | 80                         | 50.95 | 33.75 |
| 25   | 36.00 | 26.47 | 85                         | 52.26 | 34.32 |
| 30   | 37.49 | 27.27 | 90                         | 53.56 | 34.88 |
| 35   | 38.93 | 28.02 | 95                         | 54.84 | 35.42 |
| 40   | 40.32 | 28.73 | 100                        | 56.08 | 35.93 |
| 45   | 41.71 | 29.43 | 105                        | 57.35 | 36.45 |
| 50   | 43.10 | 30.12 | *108.0                     | 58.11 | 36.75 |
| 55   | 44.49 | 30.79 | * B.P. saturated solution. |       |       |

## Simultaneous Solubility of Potassium Chloride—Sodium Chloride. (Precht and Wittjen, 1881).

A solution which is saturated with both salts contains  $W_1$  gms. of KCl and  $W_2$  gms. of NaCl to 100 gms. of water.

| °C. | W <sub>1</sub> | W <sub>2</sub> | °C. | W <sub>1</sub> | W <sub>2</sub> |
|-----|----------------|----------------|-----|----------------|----------------|
| 10  | 12.5           | 29.7           | 60  | 24.6           | 27.2           |
| 20  | 14.7           | 29.2           | 70  | 27.3           | 26.8           |
| 30  | 17.2           | 28.7           | 80  | 30.0           | 26.4           |
| 40  | 19.5           | 28.2           | 90  | 32.9           | 26.1           |
| 50  | 22.0           | 27.7           | 100 | 34.7           | 25.8           |

## Solubility of Potassium Chloride in Magnesium Chloride Solutions

(Precht and Wittjen, 1881).

A solution of  $\text{MgCl}_2$  and  $\text{KCl}$ , which when saturated with  $\text{KCl}$  at  $10^\circ\text{C}$ . contains 30, 21.2, etc., gms.  $\text{MgCl}_2$  in 100 gms. of solution, contains, when saturated with  $\text{KCl}$  at the temperatures given, S gms.  $\text{KCl}$  in 100 gms. of solution.

| $^\circ\text{C}$ . | 30% $\text{MgCl}_2$<br>S. | 21.2% $\text{MgCl}_2$<br>S. | 15% $\text{MgCl}_2$<br>S. | 11% $\text{MgCl}_2$<br>S. |
|--------------------|---------------------------|-----------------------------|---------------------------|---------------------------|
| 10                 | 1.9                       | 5.3                         | 9.9                       | 14.3                      |
| 20                 | 2.6                       | 6.5                         | 11.3                      | 15.9                      |
| 30                 | 3.4                       | 7.3                         | 12.7                      | 17.5                      |
| 40                 | 4.2                       | 8.8                         | 14.2                      | 19.0                      |
| 50                 | 5.0                       | 10.0                        | 15.6                      | 20.5                      |
| 60                 | 5.8                       | 11.2                        | 17.0                      | 21.9                      |
| 70                 | 6.5                       | 12.4                        | 18.3                      | 23.2                      |
| 80                 | 7.3                       | 13.6                        | 19.5                      | 24.5                      |
| 90                 | 8.1                       | 14.7                        | 20.8                      | 25.8                      |
| 100                | 8.9                       | 15.9                        | 22.1                      | 27.1                      |

## Simultaneous Solubility of Potassium Chloride and Sodium Chloride in 20% Magnesium Chloride Solutions. (Precht and Wittjen, 1881).

A solution of  $\text{MgCl}_2$ ,  $\text{KCl}$  and  $\text{NaCl}$ , which when saturated both with  $\text{KCl}$  and with  $\text{NaCl}$  at  $10^\circ\text{C}$ . contains 20 gms.  $\text{MgCl}_2$  in 100 gms. of solution, contains when saturated with both salts at the temperatures given,  $S_1$  gms. of  $\text{KCl}$  and  $S_2$  gms. of  $\text{NaCl}$  in 100 gms. of solution.

| $^\circ\text{C}$ . | % $\text{KCl}$<br>$S_1$ | % $\text{NaCl}$<br>$S_2$ | $^\circ\text{C}$ . | % $\text{KCl}$<br>$S_1$ | % $\text{NaCl}$<br>$S_2$ |
|--------------------|-------------------------|--------------------------|--------------------|-------------------------|--------------------------|
| 10                 | 4.2                     | 5.7                      | 60                 | 8.9                     | 6.3                      |
| 20                 | 5.1                     | 5.8                      | 70                 | 9.9                     | 6.4                      |
| 30                 | 6.0                     | 5.9                      | 80                 | 10.9                    | 6.6                      |
| 40                 | 6.9                     | 6.0                      | 90                 | 11.9                    | 6.7                      |
| 50                 | 7.9                     | 6.1                      | 100                | 13.0                    | 6.9                      |

## Solubility of Potassium Chromate.

(Koppel and Blumenthal, 1907).

| °C. | $K_2CrO_4$ |       | °C.    | $K_2CrO_4$ |      |
|-----|------------|-------|--------|------------|------|
|     | W.         | S.    |        | W.         | S.   |
| 0   | 57.11      | 36.35 | 55     | 72.4       | 42.0 |
| 5   | 58.2       | 36.8  | 60     | 74.60      | 42.7 |
| 10  | 59.49      | 37.3  | 65     | 75.6       | 43.1 |
| 15  | 60.8       | 37.8  | 70     | 77.2       | 43.6 |
| 20  | 62.25      | 38.3  | 75     | 78.7       | 44.0 |
| 25  | 63.7       | 38.9  | 80     | 80.3       | 44.5 |
| 30  | 65.11      | 39.4  | 85     | 81.9       | 45.0 |
| 35  | 66.49      | 39.9  | 90     | 83.6       | 45.5 |
| 40  | 67.9       | 40.4  | 95     | 85.2       | 46.0 |
| 45  | 69.48      | 41.0  | 100    | 86.8       | 46.5 |
| 50  | 70.9       | 41.5  | *105.8 | 88.8       | 47.0 |

\* B.P. saturated solution.

## Solubility of Potassium Dichromate.

(Koppel and Blumenthal, 1907).

| °C. | $K_2Cr_2O_7$ |       | °C.    | $K_2Cr_2O_7$ |       |
|-----|--------------|-------|--------|--------------|-------|
|     | W.           | S.    |        | W.           | S.    |
| 0   | 4.64         | 4.43  | 55     | 37.99        | 27.53 |
| 5   | 5.89         | 5.56  | 60     | 45.44        | 31.24 |
| 10  | 7.66         | 7.11  | 65     | 47.10        | 32.02 |
| 15  | 9.60         | 8.76  | 70     | 53.68        | 34.93 |
| 20  | 12.12        | 10.81 | 75     | 59.91        | 37.42 |
| 25  | 14.83        | 12.91 | 80     | 66.41        | 39.91 |
| 30  | 18.13        | 15.35 | 85     | 73.43        | 42.34 |
| 35  | 21.70        | 17.83 | 90     | 81.31        | 44.85 |
| 40  | 25.41        | 20.26 | 95     | 89.85        | 47.33 |
| 45  | 29.33        | 22.68 | 100    | 98.90        | 49.72 |
| 50  | 33.43        | 25.05 | *104.8 | 108.20       | 51.97 |

\* B.P. saturated solution.

## Solubility of Potassium Ferricyanide. (Wallace, 1885).

| °C.  | $K_3Fe(CN)_6$<br>W. | °C.   | $K_3Fe(CN)_6$<br>W. |
|------|---------------------|-------|---------------------|
| 4.4  | 33.0                | 37.8  | 58.8                |
| 10   | 36.6                | 100   | 77.5                |
| 15.6 | 40.8                | 104.4 | 82.6                |

## Solubility of Potassium Ferrocyanide. (Thomson, 1896).

|         | W.   |               |
|---------|------|---------------|
| 12.2°C. | 27.8 | $K_4Fe(CN)_6$ |
| 37.7°C. | 65.8 | „             |
| 65.5°C. | 87.6 | „             |
| 96.3°C. | 90.6 | „             |

## Solubility of Potassium Hydroxide. (Pickering, 1893 : Ferchland, 1902).

| °C.    | KOH   |      | °C.   | KOH |       | °C.    | KOH   |       |
|--------|-------|------|-------|-----|-------|--------|-------|-------|
|        | W.    | S.   |       | W.  | S.    |        | W.    | S.    |
| -2.2*  | 3.7   | 3.6  | -23.2 | 85  | 45.9  | +32.5§ | 135   | 57.44 |
| -20.7* | 22.5  | 18.4 | 0     | 97  | 49.2  | 50     | 140   | 58.33 |
| -65.2* | 44.5  | 30.8 | +10   | 103 | 50.7  | 100    | 178   | 64.03 |
| -36.2† | 36.2  | 26.6 | 15    | 107 | 51.7  | 125    | 213   | 68.06 |
| -32.7† | 77.94 | 43.8 | 20    | 112 | 52.8  | 143    | 311.7 | 75.73 |
| -33‡   | 80    | 44.4 | 30    | 125 | 55.76 |        |       |       |

Solid phases : \* Ice; †  $KOH \cdot 4H_2O$ ; ‡  $KOH \cdot 4H_2O + KOH \cdot 2H_2O$ ;  
§  $KOH \cdot 2H_2O + KOH \cdot H_2O$ .

## Solubility of Potassium Iodide. (Mulder).

| °C. | KI.<br>W. | °C. | KI.<br>W. | °C. | KI.<br>W. |
|-----|-----------|-----|-----------|-----|-----------|
| 0   | 127.9     | 40  | 160       | 80  | 192       |
| 1   | 128.7     | 41  | 161       | 81  | 193       |
| 2   | 129.6     | 42  | 162       | 82  | 194       |
| 3   | 130.4     | 43  | 163       | 83  | 195       |
| 4   | 131.2     | 44  | 164       | 84  | 196       |
| 5   | 132.1     | 45  | 164       | 85  | 197       |
| 6   | 132.9     | 46  | 165       | 86  | 197       |
| 7   | 133.7     | 47  | 166       | 87  | 198       |
| 8   | 134.5     | 48  | 167       | 88  | 199       |
| 9   | 135.3     | 49  | 168       | 89  | 200       |
| 10  | 136.1     | 50  | 168       | 90  | 201       |
| 11  | 137.0     | 51  | 169       | 91  | 202       |
| 12  | 137.8     | 52  | 170       | 92  | 202       |
| 13  | 138.6     | 53  | 171       | 93  | 203       |
| 14  | 139.4     | 54  | 172       | 94  | 204       |
| 15  | 140.2     | 55  | 172       | 95  | 205       |
| 16  | 141.0     | 56  | 173       | 96  | 206       |
| 17  | 141.8     | 57  | 174       | 97  | 207       |
| 18  | 142.6     | 58  | 175       | 98  | 208       |
| 19  | 143.4     | 59  | 175       | 99  | 208       |
| 20  | 144.2     | 60  | 176       | 100 | 209       |
| 21  | 145.1     | 61  | 177       | 101 | 210       |
| 22  | 145.9     | 62  | 178       | 102 | 211       |
| 23  | 146.7     | 63  | 179       | 103 | 212       |
| 24  | 147.5     | 64  | 180       | 104 | 213       |
| 25  | 148.3     | 65  | 180       | 105 | 213       |
| 26  | 149.1     | 66  | 181       | 106 | 214       |
| 27  | 149.9     | 67  | 182       | 107 | 215       |
| 28  | 150.7     | 68  | 183       | 108 | 216       |
| 29  | 151.5     | 69  | 184       | 109 | 217       |
| 30  | 152.3     | 70  | 184       | 110 | 218       |
| 31  | 153       | 71  | 185       | 111 | 219       |
| 32  | 154       | 72  | 186       | 112 | 220       |
| 33  | 155       | 73  | 187       | 113 | 220       |
| 34  | 156       | 74  | 188       | 114 | 221       |
| 35  | 156       | 75  | 188       | 115 | 222       |
| 36  | 157       | 76  | 189       | 116 | 223       |
| 37  | 158       | 77  | 190       | 117 | 223.6     |
| 38  | 159       | 78  | 191       |     |           |
| 39  | 160       | 79  | 192       |     |           |

## Solubility of Potassium Nitrate. (Berkeley, 1904).

| °C. | KNO <sub>3</sub> |       | °C.    | KNO <sub>3</sub> |       |
|-----|------------------|-------|--------|------------------|-------|
|     | W.               | S.    |        | W.               | S.    |
| 0   | 13.13            | 11.62 | 60     | 101.07           | 50.29 |
| 5   | 17.71            | 15.05 | 65     | 108.80           | 52.11 |
| 10  | 21.94            | 17.99 | 70     | 136.35           | 57.69 |
| 15  | 26.40            | 20.89 | 75     | 153.87           | 60.61 |
| 20  | 33.02            | 24.82 | 80     | 171.10           | 63.11 |
| 25  | 39.76            | 28.45 | 85     | 188.07           | 65.29 |
| 30  | 46.76            | 31.86 | 90     | 204.92           | 67.20 |
| 35  | 55.57            | 35.72 | 95     | 226.02           | 69.33 |
| 40  | 65.52            | 39.58 | 100    | 248.64           | 71.32 |
| 45  | 75.09            | 42.89 | 105    | 271.02           | 73.05 |
| 50  | 84.04            | 45.66 | 110    | 293.62           | 74.60 |
| 55  | 93.00            | 48.19 | *114.0 | 311.64           | 75.71 |

\* B.P. saturated solution.

## Solubility of Mixtures of Potassium Nitrate and Sodium Nitrate at 20° C.

(Carnelly and Thomson, 1888).

| % NaNO <sub>3</sub><br>before soln. | Grm. mixture<br>in 100 grm. water. | Grm. NaNO <sub>3</sub><br>dissolved. | Grm. KNO <sub>3</sub><br>dissolved. | % NaNO <sub>3</sub> on<br>evaporation. |
|-------------------------------------|------------------------------------|--------------------------------------|-------------------------------------|--|
| 100                                 | 86.8                               | 86.8                                 | 0                                   | 100                                    |
| 90                                  | 109.6                              | 96.4                                 | 13.2                                | 88                                     |
| 80                                  | 136.5                              | 98.0                                 | 38.5                                | 71.8                                   |
| 70                                  | 136.3                              | -                                    | -                                   | -                                      |
| 60                                  | 137.6                              | 90.0                                 | 47.6                                | 65.4                                   |
| 50                                  | 106.1                              | 66.0                                 | 40.1                                | 62.2                                   |
| 45.7                                | 88.0                               | 53.3                                 | 34.7                                | 60.6                                   |
| 40                                  | 81.1                               | 45.6                                 | 35.6                                | 56.2                                   |
| 30                                  | 73.5                               | -                                    | -                                   | -                                      |
| 20                                  | 54.1                               | 20.8                                 | 33.3                                | 38.5                                   |
| 10                                  | 40.9                               | 9.4                                  | 31.5                                | 22.9                                   |
| 0                                   | 33.6                               | 0                                    | 33.6                                | 0                                      |

## Solubility of Potassium Sulphate.

(Berkeley, 1904).

| °C. | $K_2SO_4$ . |       | °C.    | $K_2SO_4$ . |       |
|-----|-------------|-------|--------|-------------|-------|
|     | W.          | S.    |        | W           | S.    |
| 0   | 7.40        | 6.89  | 60     | 18.81       | 15.83 |
| 5   | 8.34        | 7.70  | 65     | 19.01       | 15.97 |
| 10  | 9.29        | 8.50  | 70     | 19.83       | 16.55 |
| 15  | 10.24       | 9.29  | 75     | 20.66       | 17.12 |
| 20  | 11.18       | 10.06 | 80     | 21.35       | 17.59 |
| 25  | 12.13       | 10.83 | 85     | 22.05       | 18.07 |
| 30  | 13.07       | 11.56 | 90     | 22.74       | 18.53 |
| 35  | 14.03       | 12.30 | 95     | 23.40       | 18.96 |
| 40  | 14.99       | 13.04 | 100    | 24.06       | 19.39 |
| 45  | 15.85       | 13.68 | *101.1 | 24.21       | 19.49 |
| 50  | 16.63       | 14.26 |        |             |       |
| 55  | 17.41       | 14.83 |        |             |       |

\* B.P. of saturated solution.

## Solubility of Potassium Thiocyanate.

(Rudorff, 1869).

|       | W.    |      |
|-------|-------|------|
| 0°C.  | 177.2 | KCNS |
| 20°C. | 217   | "    |

## Solubility of Potassium Iodate. (Kremers, 1858).

| °C. | $KIO_3$ . | °C. | $KIO_3$ . |
|-----|-----------|-----|-----------|
|     | W.        |     | W.        |
| 0   | 4.73      | 60  | 18.5      |
| 20  | 8.13      | 80  | 24.8      |
| 40  | 12.8      | 100 | 32.2      |

## Solubility of Acid Potassium Oxalate. (Alluard).

| °C. | $KHC_2O_4$ . | °C. | $KHC_2O_4$ . |
|-----|--------------|-----|--------------|
|     | W.           |     | W.           |
| 0   | 2.2          | 60  | 20.5         |
| 10  | 3.1          | 80  | 34.7         |
| 20  | 5.2          | 100 | 51.5         |
| 40  | 10.5         |     |              |

## Solubility of Salicylic Acid.

(See Solubility of Benzoic Acid).

## Solubility of Silver Chloride in Salt Solutions.

(Hahn, 1877)

The figures under % Salt are gms. salt in 100 gms. solution. Vogel (and others) give sometimes very different values for solubility of AgCl.

| Salt.              | % Salt. | Saturated<br>at °C. | % AgCl |
|--------------------|---------|---------------------|--------|
| KCl                | 24.95   | 19.6                | 0.0776 |
| NaCl               | 25.96   | 19.6                | 0.1053 |
| NH <sub>4</sub> Cl | 28.45   | 24.5                | 0.3397 |
| CaCl <sub>2</sub>  | 41.26   | 24.5                | 0.5713 |
| MgCl <sub>2</sub>  | 36.35   | 24.5                | 0.5313 |
| BaCl <sub>2</sub>  | 27.32   | 24.5                | 0.0570 |
| FeCl <sub>2</sub>  | 30.70   | —                   | 0.1686 |
| FeCl <sub>3</sub>  | 37.48   | —                   | 0.0058 |
| MnCl <sub>2</sub>  | 43.85   | 24.5                | 0.1996 |
| ZnCl <sub>2</sub>  | 53.34   | —                   | 0.0134 |
| CuCl <sub>2</sub>  | 44.48   | 24.5                | 0.0532 |
| PbCl <sub>2</sub>  | 0.99    | 24.5                | 0.0000 |

## Solubility of Silver Nitrate.

(From mean values Landolt Börnstein's tables, 1905).

| °C. | AgNO <sub>3</sub> |    | °C. | AgNO <sub>3</sub> |    |
|-----|-------------------|----|-----|-------------------|----|
|     | W.                | S. |     | W.                | S. |
| 0   | 115               | 53 | 70  | 550               | 85 |
| 10  | 160               | 61 | 80  | 650               | 87 |
| 20  | 215               | 68 | 90  | 760               | 88 |
| 30  | 270               | 73 | 100 | 910               | 90 |
| 40  | 335               | 77 | 110 | 1110              | 92 |
| 50  | 400               | 80 | 125 | 1941              | 95 |
| 60  | 470               | 82 |     |                   |    |

## Solubility of Sodium Acetate. (Osann).

|       | W.   |   |
|-------|------|---|
| 6°C.  | 25.7 | CH <sub>3</sub> COONa+3H <sub>2</sub> O |
| 37°C. | 41.7 | „                                       |
| 48°C. | 58.8 | „                                       |



## Solubility of Sodium Bicarbonate. (Fedotieff, 1904).

| °C. | NaHCO <sub>3</sub> . |      | °C. | NaHCO <sub>3</sub> . |       |
|-----|----------------------|------|-----|----------------------|-------|
|     | W.                   | S.   |     | W.                   | S.    |
| 0   | 6.90                 | 6.45 | 25  | 10.24                | 9.29  |
| 5   | 7.51                 | 6.98 | 30  | 11.02                | 9.93  |
| 10  | 8.15                 | 7.54 | 35  | 11.86                | 10.60 |
| 15  | 8.80                 | 8.09 | 40  | 12.82                | 11.36 |
| 20  | 9.51                 | 8.70 | 45  | 13.86                | 12.17 |

Note.—In these determinations  $p\text{CO}_2 + p\text{H}_2\text{O} = 1$  atmosphere.

## Solubility of Sodium Bromate, Sodium Chlorate and Sodium Iodate. (Kremers, 1855).

| °C. | NaBrO <sub>3</sub> | NaClO <sub>3</sub> | NaIO <sub>3</sub> | °C. | NaBrO <sub>3</sub> | NaClO <sub>3</sub> | NaIO <sub>3</sub> |
|-----|--------------------|--------------------|-------------------|-----|--------------------|--------------------|-------------------|
|     | W.                 | W.                 | W.                |     | W.                 | W.                 | W.                |
| 0   | 27.54              | 81.9               | 2.52              | 80  | 75.75              | 175.6              | 27.70             |
| 20  | 34.48              | 99                 | 9.07              | 100 | 90.90              | 204.1              | 33.90             |
| 40  | 50.25              | 123.5              | 14.39             | 120 | —                  | 333.3              | —                 |
| 60  | 62.50              | 147.1              | 20.88             |     |                    |                    |                   |

## Solubility of Sodium Bromide. (De Coppet, 1883)

| °C. | NaBr. |       | °C.      | NaBr. |       |
|-----|-------|-------|----------|-------|-------|
|     | S.    | W.    |          | S.    | W.    |
| -20 | 41.8  | 71.8  | *50.7    | 53.9  | 116.9 |
| 10  | 42.9  | 75.1  | 60       | 53.9  | 116.9 |
| 0   | 44.3  | 79.5  | 70       | 54.0  | 117.4 |
| +10 | 45.7  | 84.2  | 80       | 54.2  | 118.3 |
| 20  | 47.5  | 90.5  | 90       | 54.5  | 119.8 |
| 30  | 49.3  | 97.2  | 100      | 54.8  | 121.2 |
| 40  | 51.4  | 105.8 | 110      | 55.1  | 122.7 |
| 50  | 53.7  | 116.0 | 121 B.P. | —     | —     |

\* Transition point: Hydrate with 2 aq. + NaBr.

## Solubility of Sodium Carbonate (Mulder).

| °C. | Na <sub>2</sub> CO <sub>3</sub> ,<br>W. | °C.   | Na <sub>2</sub> CO <sub>3</sub> ,<br>W. |
|-----|---|-------|---|
| 0   | 7.0                                     | *32.5 | 46.2                                    |
| 5   | 9.5                                     | 35    | 46.2                                    |
| 10  | 12.5                                    | 40    | 46.1                                    |
| 15  | 16.4                                    | 60    | 46.0                                    |
| 20  | 21.5                                    | 80    | 45.8                                    |
| 25  | 28.2                                    | 100   | 45.5                                    |
| 30  | 37.8                                    | 105   | 45.2                                    |

\* Transition point: Hydrate with 10 aq. + 1 aq.

## Solubilities of Sodium Carbonate and Sodium Bicarbonate in Sodium Chloride Solutions at 15°C. (Reich).

| Grms. Na <sub>2</sub> CO <sub>3</sub> in<br>% NaCl 100 grms. NaCl soln. |       | Grms. Na <sub>2</sub> CO <sub>3</sub> in<br>% NaCl 100 grms. NaCl soln. |       |
|---|-------|---|-------|
| 0   | 16.41 | 12  | 10.49 |
| 1   | 15.72 | 13  | 10.24 |
| 2   | 15.06 | 14  | 10.04 |
| 3   | 14.44 | 15  | 9.88  |
| 4   | 13.85 | 16  | 9.76  |
| 5   | 13.30 | 17  | 9.69  |
| 6   | 12.78 | 18  | 9.65  |
| 7   | 12.31 | 19  | 9.67  |
| 8   | 11.86 | 20  | 9.72  |
| 9   | 11.46 | 21  | 9.83  |
| 10  | 10.10 | 22  | 10.00 |
| 11  | 10.77 |   |       |

After precipitating bicarbonate by carbon dioxide:

| Grms. NaHCO <sub>3</sub> in<br>% NaCl 100 grms. NaCl soln. |      |
|--|------|
| 10.64  | 3.00 |
| 15.80  | 1.87 |
| 21.82  | 1.06 |

## Solubility of Sodium Chloride. (Berkeley, 1904).

| °C. | NaCl. |       | °C.    | NaCl. |       |
|-----|-------|-------|--------|-------|-------|
|     | W.    | S.    |        | W.    | S.    |
| 0   | 35.70 | 26.31 | 60     | 37.28 | 27.16 |
| 5   | 35.78 | 26.35 | 65     | 37.47 | 27.26 |
| 10  | 35.82 | 26.37 | 70     | 37.64 | 27.35 |
| 15  | 35.85 | 26.39 | 75     | 37.81 | 27.44 |
| 20  | 35.97 | 26.45 | 80     | 38.05 | 27.56 |
| 25  | 36.09 | 26.52 | 85     | 38.31 | 27.70 |
| 30  | 36.20 | 26.58 | 90     | 38.57 | 27.83 |
| 35  | 36.34 | 26.65 | 95     | 38.90 | 28.01 |
| 40  | 36.48 | 26.73 | 100    | 39.24 | 28.18 |
| 45  | 36.60 | 26.79 | 105    | 39.34 | 28.23 |
| 50  | 36.83 | 26.92 | *107.0 | 39.65 | 28.39 |
| 55  | 36.96 | 26.99 |        |       |       |

\* B.P. saturated solution.

Solubility of Sodium Chromate.  
(Mylius and Funk, 1900).

| °C. | Na <sub>2</sub> CrO <sub>4</sub><br>W. | °C. | Na <sub>2</sub> CrO <sub>4</sub><br>W. | °C. | Na <sub>2</sub> CrO <sub>4</sub><br>W. |
|-----|--|-----|--|-----|--|
| 0   | 31.7                                   | 40  | 96                                     | 68  | 123.5                                  |
| 10  | 50.2                                   | 50  | 105                                    | 80  | 124                                    |
| 21  | 89.9                                   | 60  | 115                                    | 100 | 126                                    |

Solubility of Sodium Dichromate.  
(Mylius and Funk, 1900).

| °C. | Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub><br>W. | °C. | Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub><br>W. | °C. | Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub><br>W. |
|-----|--|-----|--|-----|--|
| 0   | 163  | 40  | 220  | 80  | 386  |
| 10  | 170  | 50  | 248  | 93  | 432  |
| 20  | 180  | 60  | 283  | 98  | 433  |
| 30  | 197  | 70  | 323  |     |  |

## Solubility of Sodium Ferrocyanide (Conroy, 1898).

|         | W.   |                                     |
|---------|------|-------------------------------------|
| 20°C.   | 17.9 | $\text{Na}_4\text{Fe}(\text{CN})_6$ |
| 42°C.   | 30.2 | "                                   |
| 80°C.   | 59.2 | "                                   |
| 98.5°C. | 63.0 | "                                   |

## Solubility of Sodium Hydroxide. (Pickering, 1893; Mylius and Funk, 1900).

| °C.   | NaOH. |      | °C.  | NaOH. |      | °C.    | NaOH. |      |
|-------|-------|------|------|-------|------|--------|-------|------|
|       | W.    | S.   |      | W.    | S.   |        | W.    | S.   |
| - 7.8 | 8.7   | 8.0  | +10  | 51.5  | 34.0 | 50     | 145   | 59.2 |
| -20   | 19.1  | 16.0 | 15.5 | 63.5  | 38.9 | 60     | 174   | 63.5 |
| -28*  | 23.5  | 19.0 | 5†   | 83.5  | 45.5 | 64.3   | 222.3 | 69.0 |
| -24   | 28.5  | 22.2 | 12§  | 103   | 50.7 | 61.8** | 288   | 74.2 |
| -17.7 | 32.5  | 24.5 | 20   | 109   | 52.2 | 80     | 313   | 75.8 |
| 0     | 42.0  | 29.6 | 30   | 119   | 54.3 | 110    | 365   | 78.5 |
| + 5   | 47.5  | 32.2 | 40   | 129   | 56.3 | 192    | 521   | 83.9 |

Solid phases at transition points : \* ice +  $2\text{NaOH} \cdot 7\text{H}_2\text{O}$ ;  
 †  $2\text{NaOH} \cdot 7\text{H}_2\text{O}$  +  $\text{NaOH} \cdot 2\text{H}_2\text{O}$ ; §  $\text{NaOH} \cdot 2\text{H}_2\text{O}$  +  $\text{NaOH} \cdot \text{H}_2\text{O}$ ;  
 \*\*  $\text{NaOH} \cdot \text{H}_2\text{O}$  +  $\text{NaOH}$ .

## Solubility of Sodium Iodide. (De Ccpet, 1883).

| °C. | NaI. |       | °C. | NaI. |       |
|-----|------|-------|-----|------|-------|
|     | S.   | W.    |     | S.   | W.    |
| 0   | 61.4 | 151.9 | 60  | 72.0 | 257.1 |
| 10  | 62.8 | 168.8 | *65 | 74.4 | 290.6 |
| 20  | 64.2 | 179.3 | 70  | 74.5 | 292.2 |
| 30  | 65.5 | 189.8 | 80  | 74.7 | 295.3 |
| 40  | 67.2 | 204.9 | 90  | 74.9 | 298.4 |
| 50  | 69.5 | 220.6 | 100 | 75.1 | 301.6 |

\* Transition point : Hydrate with 2 aq. + NaI.

# Solubility of Sodium Nitrate. (Berkeley, 1904)

| °C. | NaNO <sub>3</sub> . |       | °C.    | NaNO <sub>3</sub> . |       |
|-----|---------------------|-------|--------|---------------------|-------|
|     | W.                  | S.    |        | W.                  | S.    |
| 0   | 73.07               | 42.22 | 65     | 130.30              | 56.58 |
| 5   | 76.77               | 43.43 | 70     | 135.98              | 57.62 |
| 10  | 80.45               | 44.58 | 75     | 141.72              | 58.63 |
| 15  | 84.16               | 45.70 | 80     | 148.12              | 59.70 |
| 20  | 88.11               | 46.84 | 85     | 154.66              | 60.73 |
| 25  | 92.13               | 47.95 | 90     | 161.27              | 61.72 |
| 30  | 96.15               | 49.02 | 95     | 169.42              | 62.88 |
| 35  | 100.60              | 50.15 | 100    | 177.66              | 63.98 |
| 40  | 105.16              | 51.26 | 105    | 185.77              | 65.01 |
| 45  | 109.58              | 52.29 | 110    | 194.06              | 65.99 |
| 50  | 115.09              | 53.51 | 115    | 202.28              | 66.92 |
| 55  | 119.82              | 54.51 | *119.0 | 208.84              | 67.62 |
| 60  | 124.56              | 55.47 |        |                     |       |

\* B.P. saturated solution.

# Solubility of Sodium Phosphate. (Dans and Schreiner, Shiomi, 1910).

| °C.        | Na <sub>2</sub> HPO <sub>4</sub> . |       | °C.          | Na <sub>2</sub> HPO <sub>4</sub> . |       |
|------------|------------------------------------|-------|--------------|------------------------------------|-------|
|            | W.                                 | S.    |              | W.                                 | S.    |
| 0          | 2.51                               | 2.45  | * (ii) 48.35 | 79.00                              | 44.13 |
| 5          | 2.90                               | 2.82  | 50           | 80.16                              | 44.50 |
| 10         | 3.50                               | 3.38  | 55           | 85.44                              | 46.07 |
| 15         | 5.16                               | 4.90  | 60           | 91.41                              | 47.76 |
| 20         | 7.80                               | 7.40  | 65           | 93.39                              | 48.29 |
| 25         | 12.47                              | 11.08 | 70           | 94.99                              | 48.72 |
| 30         | 20.64                              | 17.11 | 75           | 95.81                              | 48.93 |
| 35         | 43.96                              | 30.54 | 80           | 96.63                              | 49.14 |
| * (i) 35.4 | 46.11                              | 31.56 | 85           | 97.27                              | 49.31 |
| 40         | 54.34                              | 35.21 | 90           | 97.81                              | 49.45 |
| 45         | 69.04                              | 40.84 | 91           | 98.15                              | 49.54 |

\* Transition points: (i) Hydrate with 12 aq. and 7 aq.; (ii) Hydrate with 7 aq. and 2 aq.

## Solubility of Sodium Sulphate. (Berkeley, 1904).

| °C.   | Na <sub>2</sub> SO <sub>4</sub> |       | °C.    | Na <sub>2</sub> SO <sub>4</sub> |       |
|-------|---------------------------------|-------|--------|---------------------------------|-------|
|       | W.                              | S.    |        | W.                              | S.    |
| 0     | 4.67                            | 4.46  | 55     | 45.96                           | 31.49 |
| 5     | 6.73                            | 6.31  | 60     | 45.24                           | 31.15 |
| 10    | 9.08                            | 8.32  | 56     | 44.65                           | 30.87 |
| 15    | 13.54                           | 11.92 | 70     | 44.10                           | 30.60 |
| 20    | 20.41                           | 16.95 | 75     | 43.60                           | 30.36 |
| 25    | 27.89                           | 21.81 | 80     | 43.28                           | 30.21 |
| 30    | 40.95                           | 29.05 | 85     | 42.97                           | 30.06 |
| *32.5 | 49.70                           | 33.20 | 90     | 42.66                           | 29.90 |
| 35    | 49.09                           | 32.93 | 95     | 42.46                           | 29.80 |
| 40    | 48.20                           | 32.51 | 100    | 42.26                           | 29.72 |
| 45    | 47.41                           | 32.16 | †101.9 | 42.18                           | 29.67 |
| 50    | 46.72                           | 31.84 |        |                                 |       |

\* Transition point: Hydrate with 10 aq. + Na<sub>2</sub>SO<sub>4</sub>.

† B.P. saturated solution.

(Richards and Yngve, 1918).

Note.—Exact determinations, using Na<sub>2</sub>SO<sub>4</sub>·10H<sub>2</sub>O, for temperature measurements between 15° and 25°C. to 0.01°.

| °C.    | Na <sub>2</sub> SO <sub>4</sub> | °C. | Na <sub>2</sub> SO <sub>4</sub> |
|--------|---------------------------------|-----|---------------------------------|
|        | W.                              |     | W.                              |
| 15.000 | 13.181                          | 21  | 20.549                          |
| 16     | 14.185                          | 22  | 22.155                          |
| 17     | 15.268                          | 23  | 23.888                          |
| 18     | 16.437                          | 24  | 25.762                          |
| 19     | 17.698                          | 25  | 27.795                          |
| 20     | 19.064                          |     |                                 |

## Solubility of Sodium Sulphite.

(Hartley and Barrett, 1909).

| °C.  | Na <sub>2</sub> SO <sub>3</sub> |       | °C. | Na <sub>2</sub> SO <sub>3</sub> |       |
|------|---------------------------------|-------|-----|---------------------------------|-------|
|      | W.                              | S.    |     | W.                              | S.    |
| -1.9 | 13.09                           | 11.57 | 25  | 28.5                            | 22.18 |
| 0    | 13.90                           | 12.20 | 30  | 28.5                            | 22.18 |
| +5   | 16.32                           | 14.03 | 37  | 28.04                           | 21.90 |
| 10   | 19.25                           | 16.14 | 47  | 28.13                           | 21.95 |
| 15   | 22.95                           | 18.67 | 55  | 28.21                           | 22.00 |
| 20   | 26.67                           | 21.05 | 84  | 28.26                           | 22.03 |
| *22  | 28.6                            | 22.24 |     |                                 |       |

\* Transition point: Hydrate with 7 aq. + Na<sub>2</sub>SO<sub>3</sub>.

## III. LIQUIDS IN LIQUIDS.

If two liquids *A* and *B* which are not miscible in all proportions are in contact with one another, the layer containing an excess of *A* will contain a certain proportion of *B* and *vice-versa*. The solubilities vary with the temperature, rapidly near the critical solution temperature above which *A* and *B* are miscible in all proportions: some pairs of liquids show a lower critical point and are completely miscible below, partially above this temperature.

The solubilities are given as gms. of first-mentioned substance in 100 gms of mixture. Critical solution temperatures are marked with an asterisk: in many cases they are above the boiling-point of the mixture.

|  | °C. | 20   | 40   | 60   | 100  | 140   | 167*   |
|--|-----|------|------|------|------|-------|--------|
| { Aniline in water .....                             | %   | 3.1  | 3.3  | 3.8  | 7.2  | 13.5  | 48.6   |
| { Water in aniline .....                             | %   | 5.0  | 5.3  | 5.8  | 8.4  | 16.9  | 51.4   |
|  | °C. | 15   | 29   | 58   | 95   | 112   | 187.5* |
| { iso-Amyl alcohol in water                          | %   | 2.7  | 2.3  | 2.2  | 2.7  | 3.4   | 36.6   |
|  | °C. | 15.5 | —    | 69.5 | 97.3 | 122.3 | 187.5  |
| { Water in iso-amyl alcohol                          | %   | 9.3  | —    | 12.6 | 16.0 | 19.8  | 63.4   |
|  | °C. | 0    | 10.3 | 20   | 30.2 | 40.0  | 49.9   |
| Bromine in water .....                               | %   | 4.00 | 3.60 | 3.40 | 3.32 | 3.33  | 3.40   |
|  | °C. | 0    | 10   | 20   | 30   | 40    | 49     |
| Carbon bisulphide in water                           | %   | .20  | .19  | .18  | .15  | .11   | .01    |
| { Carbon bisulphide in                               | °C. | 10   | 20   | 25   | 30   | 35    | 40.5*  |
| methyl alcohol                                       | %   | 44.9 | 50.4 | 53.8 | 57.9 | 63.9  | 80.5   |
| { Methyl alcohol in CS <sub>2</sub> ....             | %   | 1.8  | 2.6  | 3.2  | 4.4  | 6.7   | 19.5   |
|  | °C. | -4   | 0    | 10   | 20   | 30    | 40     |
| { Ether in water .....                               | %   | 12.6 | 12.2 | 9.0  | 6.5  | 5.0   | 4.5    |
| { Water in ether .....                               | %   | .94  | .93  | 1.09 | 1.22 | 1.35  | 1.5    |
|  | °C. | -20  | 0    | 20   | 40   | 80    | 150*   |
| { Methyl-ethyl ketone in water                       | %   | 40.1 | 30.6 | 22.6 | 18.6 | 15.7  | 45     |
| { Water in Me-Et-ketone ..                           | %   | 10.6 | 10.4 | 9.9  | 10.4 | 14.2  | 55     |
|  | °C. | 20   | 30   | 55   | —    | —     | —      |
| { Nitrobenzene in water ..                           | %   | .19  | .22  | .27  | —    | —     | —      |
|  | °C. | 8.8  | 14.7 | 30.8 | 44.2 | 63.3  | 106.6  |
| { Water in nitrobenzene ..                           | %   | .174 | .194 | .299 | .401 | .713  | 1.53   |
|  | °C. | —    | 38   | —    | 58.8 | 65.2  | 65.3*  |
| { Phenol in water .....                              | %   | —    | 9.5  | —    | 16.2 | 34.2  | 36.5   |
|  | °C. | 20.6 | —    | 42.7 | —    | 60.2  | 65.3   |
| { Water in phenol .....                              | %   | 28.6 | —    | 35.3 | —    | 46.1  | 63.5   |
|  | °C. | 3    | 23   | 40   | 55   | 66    | 77     |
| Water in benzene .....                               | %   | .03  | .06  | .11  | .18  | .26   | .33    |
| Water in paraffin oil                                | °C. | 18   | 53   | 79   | 94   | —     | —      |
| S <sub>20</sub> <sup>20</sup> .792, b.p. 190°—250°C. | %   | .005 | .026 | .063 | .097 | —     | —      |

## Correction of Gas Volumes.

The tables below give the factor by which the volume of a gas measured at the stated pressure  $p$  mms. of mercury (corrected for temperature and gravity according to the barometric tables later), and at the stated temperature  $t^{\circ}\text{C.}$  must be multiplied to find the volume at  $0^{\circ}\text{C.}$  and 760 mms. of mercury at  $0^{\circ}\text{C.}$  and lat.  $45^{\circ}$  at sea-level. A decimal point is to be inserted before the first figure. If the gas is measured when containing aqueous vapour in amount corresponding with a pressure of  $e$  mm., the factor found opposite the pressure  $p-e$  must be used to find the volume of the dry gas at N.T.P. Values of  $e$  for saturated vapour are given in the table "Vapour Pressure of Water."

Conversely, if the density  $D_0$  at N.T.P. be known, the density at a pressure  $p$  and temperature  $t$  is found by multiplying by the factor in the table. If the density required be that of the moist gas in which the pressure of water vapour is  $e$ , this is equal to

$$D_0 \times \frac{1}{1 + \alpha t} \times \frac{p-e}{760} + w_0 \frac{1}{1 + \alpha t} \times \frac{e}{769}, \text{ where } w_0 = 0.8044.$$

The value of the coefficient of expansion assumed in calculating the table is 0.0036690, which is more nearly an average for ordinary "permanent" gases than the usual  $1/273$ . The actual values of  $\alpha$  for different gases are given in the second column of table of "Coefficients of Expansion of Gases," and for the most accurate work the requisite correction to be subtracted from the factor is calculated at 760 mm. pressure for every five degrees. Corrections greater than .00100 are not likely to be accurate to more than .0001, except for  $\text{CO}_2$ , owing to inaccuracy in  $\alpha$ .

Allowance may be made for the departure of the gas from Boyle's Law by the use of the coefficients  $A$  in the third column of the table. The coefficient  $A$  is the variation of  $p$  per cm. of mercury pressure difference from 76 cms., expressed as a fraction of  $p$  at N.T.P. The magnitude of the correction at 71 cms. pressure is given for various temperatures in the table, the correction for  $\alpha$  differences being included.

*Use of the difference columns* in the main table. The differences per  $1^{\circ}\text{C.}$  in the last column of each page may be



used for interpolating to tenths of a degree : the multiplication is carried out in the small table at the foot of each page. It should be noted (i) that the differences are to be *subtracted* for increasing temperature, and (ii) that they are correct only for the interval between the third and fourth columns of temperatures : for the second to third or four to fifth columns they are 2 units too low or too high respectively, and for the first to second or fifth to next page they are 4 units too low or too high respectively throughout.

The differences per mm. and for each tenth of a mm. are given in the top line of the multiplication table, and are to be *added*.

*Example.* To reduce to N.T.P. from  $9.3^{\circ}\text{C}$ . and 730.8 mm. The figure found for  $9^{\circ}\text{C}$ . and 730 mm. is 92982 : the corresponding difference per  $1^{\circ}\text{C}$ . is  $334 - 4 = 330$  : hence difference for  $.3^{\circ}\text{C}$ . = 99. The difference per mm. is 128, hence for .8 mm. it is 102. Required factor is  $92982 - 99 + 102 = 92985$ , with decimal point to be inserted before the first figure. The result should be accurate to  $\pm .00001$ .

An alternative method of reducing to N.T.P. the volumes of readily liquefied gases, which does not require an accurate knowledge of the compressibility or of the coefficient of expansion over the range considered, is founded on Berthelot's equation of state

$$PV = \frac{273.1+t}{273.1} \left\{ 1 - (a_t - b) \frac{1}{V} \right\} \text{ where } a_t = a_o \times \left( \frac{273.1}{273.1+t} \right)^2$$

and the values of  $a_o$  and  $b$  are calculated from the critical constants of the gas  $\theta_c^{\circ}$  absolute and  $P_c$  by the relations

$$a_o = \frac{27}{64} \left( \frac{\theta_c}{273.1} \right)^2 \frac{1}{P_c} \text{ and } b = \frac{9}{128} \times \frac{1}{273.1} \frac{\theta_c}{P_c}$$

This leads to a value of the correction factor for reducing to N.T.P.

$$\text{factor} = \frac{P}{760} \times \frac{273.1}{273.1+t} \times \frac{1}{1 + a_o \left\{ 1 - f \left( \frac{273.1}{273.1+t} \right)^2 \right\} - b(1-f)}$$

in which expression  $f$  is the approximate factor read off in the table. The correction given by this expression may be used for such gases as  $\text{SO}_2$ , of which the  $\alpha$  is not known with accuracy, but the critical constants are available.

# COEFFICIENTS OF EXPANSION AND OF COMPRESSIBILITY OF GASES IN NEIGHBOURHOOD OF ROOM CONDITIONS.

| Correction $\times 10^5$ to be subtracted from $f$ at |                      |                 |         |        |         |         |         |         |
|---|----------------------|-----------------|---------|--------|---------|---------|---------|---------|
| Gas.  | $\alpha \times 10^5$ | $A \times 10^5$ | $p$ mm. | 7.5°C. | 12.5°C. | 17.5°C. | 22.5°C. | 27.5°C. |
| Air   | 366.9 Rg. "C."       | 0.75 Ra.'       | 760     | 0      | 0       | 0       | 0       | 0       |
|   |                      |                 | 710     | 3      | 3       | 3       | 3       |         |
| N <sub>2</sub>  | 367.3 C.'            | 0.68 Ra.C.      | 760     | 3      | 5       | 6       | 7       |         |
|   |                      |                 | 710     | 6      | 7       | 9       | 10      | 11      |
| H <sub>2</sub>  | 366.1 R.M.           | -0.71 Ra J.S.   | 760     | -6     | -9      | -12     | -15     | -18     |
|   |                      |                 | 710     | -2     | -5      | -8      | -11     | -14     |
| CO  | 366.5 Rg."           | 1.07 Ra.        | 760     | -3     | -5      | -6      | -7      | -9      |
|   |                      |                 | 710     | 2      | 0       | -1      | -2      | -4      |
| CO <sub>2</sub>                                       | 373.7 to 373.4 C.'   | 8.77 Ra.        | 760     | 48     | 77      | 103     | 127     | 147     |
|   |                      |                 | 710     | 82     | 106     | 127     | 146     | 164     |
| N <sub>2</sub> O                                      | 372.9 Rg."           | 9.83 Ra.        | 760     | 43     | 69      | 92      | 115     | 134     |
|   |                      |                 | 710     | 85     | 108     | 129     | 149     | 168     |
| CN  | 388 Rg               | 25.5 L.         | 760     | 150    | 240     | 320     | 400     | 470     |
|   |                      |                 | 710     | 260    | 330     | 310     | 490     | 550     |
| SO <sub>2</sub>                                       | 398 L.               | 31.4 J.S.       | 760     | 220    | 360     | 480     | 600     | 700     |
|   |                      |                 | 710     | 350    | 470     | 580     | 680     | 780     |
| C <sub>2</sub> H <sub>2</sub>                         | 374 L.               | 9.3 L.          | 760     | 50     | 80      | 108     | 135     | 158     |
|   |                      |                 | 710     | 88     | 116     | 141     | 164     | 186     |
| NH <sub>3</sub>                                       | 386 P.'              | 20.1 J.S.       | 760     | 135    | 219     | 294     | 366     | 430     |
|   |                      |                 | 710     | 217    | 292     | 362     | 425     | 486     |
| NO  | 368 L.'              | 1.54 J.S.       | 760     | 7      | 11      | 15      | 19      | 22      |
|   |                      |                 | 710     | 76     | 79      | 82      | 84      | 86      |
| HCl   | 374 L.'              | 9.83 B.         | 760     | 50     | 80      | 108     | 135     | 158     |
|   |                      |                 | 710     | 91     | 119     | 144     | 167     | 189     |
| C <sub>2</sub> H <sub>4</sub>                         | 374 L.               | 8.2 L.          | 760     | 50     | 80      | 108     | 135     | 158     |
|   |                      |                 | 710     | 83     | 111     | 137     | 160     | 182     |
| O <sub>2</sub>  | 368 L.'              | 0.94 Ra.        | 760     | 7      | 11      | 15      | 19      | 22      |
|   |                      |                 | 710     | 11     | 15      | 18      | 22      | 25      |
| H <sub>2</sub> S                                      | 377 L'               | 10.7 L.         | 760     | 71     | 115     | 154     | 192     | 225     |
|   |                      |                 | 710     | 114    | 154     | 190     | 224     | 255     |
| Cl  | 383 L.               | —               | 760     | 113    | 184     | 247     | 308     | 362     |
| C <sub>2</sub> H <sub>6</sub>                         | 377 L.               | —               | 760     | 71     | 115     | 154     | 192     | 225     |
| CH <sub>4</sub>                                       | 368                  | —               | 760     | 7      | 11      | 15      | 19      | 22      |

Rg. Regnault, Ra. Rayleigh, C. Chappius, R. M. Richards and Marks, J. S. Jacquerod and Scheuer, B. Burt, L. Leduc (calc.), P. Perman, C' interpolated from C., C'' calculated from C, by analogy of critical data, from values for 0—100°C.

Table for Correction to N.T.P.

|     | 5°.   | 6°.   | 7°.   | 8°.   | 9°.   | Diff. |
|-----|-------|-------|-------|-------|-------|-------|
| 701 | 90575 | 90250 | 89927 | 89607 | 89288 | 321   |
| 2   | 704   | 379   | 90056 | 735   | 416   | 321   |
| 3   | 834   | 508   | 184   | 862   | 543   | 321   |
| 4   | 963   | 636   | 312   | 990   | 671   | 322   |
| 5   | 91092 | 765   | 440   | 90118 | 798   | 322   |
| 6   | 221   | 894   | 569   | 246   | 925   | 323   |
| 7   | 350   | 91023 | 697   | 374   | 90053 | 323   |
| 8   | 480   | 151   | 825   | 501   | 180   | 324   |
| 9   | 609   | 280   | 954   | 629   | 307   | 324   |
| 710 | 738   | 409   | 91082 | 757   | 435   | 325   |
| 1   | 867   | 538   | 210   | 885   | 562   | 325   |
| 2   | 997   | 666   | 338   | 91013 | 690   | 326   |
| 3   | 92126 | 795   | 467   | 141   | 817   | 326   |
| 4   | 255   | 924   | 595   | 268   | 944   | 326   |
| 5   | 384   | 92052 | 723   | 396   | 91072 | 327   |
| 6   | 513   | 181   | 852   | 524   | 199   | 327   |
| 7   | 643   | 310   | 980   | 652   | 326   | 328   |
| 8   | 772   | 439   | 92108 | 780   | 454   | 328   |
| 9   | 901   | 567   | 236   | 908   | 581   | 329   |
| 720 | 93030 | 696   | 365   | 92035 | 709   | 329   |
| 1   | 159   | 825   | 493   | 163   | 836   | 330   |
| 2   | 289   | 954   | 621   | 291   | 963   | 330   |
| 3   | 418   | 93082 | 749   | 419   | 92091 | 331   |
| 4   | 547   | 211   | 878   | 547   | 218   | 331   |
| 5   | 676   | 340   | 93006 | 675   | 345   | 331   |
| 6   | 805   | 469   | 134   | 802   | 473   | 332   |
| 7   | 935   | 597   | 263   | 930   | 600   | 332   |
| 8   | 94064 | 726   | 391   | 93058 | 728   | 333   |
| 9   | 193   | 855   | 519   | 186   | 855   | 333   |
| 730 | 322   | 984   | 647   | 314   | 982   | 334   |
| 1   | 451   | 94112 | 776   | 442   | 93110 | 334   |
| 2   | 581   | 241   | 904   | 569   | 237   | 335   |
| 3   | 710   | 370   | 94032 | 697   | 364   | 335   |
| 4   | 839   | 499   | 161   | 825   | 492   | 336   |
| 5   | 968   | 627   | 289   | 953   | 619   | 336   |

| Diff. | .1. | .2. | .3. | .4. | .5. | .6. | .7. | .8. | .9. |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 128   | 13  | 26  | 38  | 51  | 64  | 77  | 90  | 102 | 115 |
| 322   | 32  | 64  | 97  | 129 | 161 | 193 | 225 | 258 | 290 |
| 325   | 32  | 65  | 97  | 130 | 162 | 195 | 227 | 260 | 292 |
| 328   | 33  | 66  | 98  | 131 | 164 | 197 | 230 | 262 | 295 |
| 331   | 33  | 66  | 99  | 132 | 165 | 199 | 232 | 265 | 298 |
| 334   | 33  | 67  | 100 | 134 | 167 | 200 | 234 | 267 | 301 |
| 337   | 34  | 67  | 101 | 135 | 168 | 202 | 236 | 270 | 303 |

|     | 5°.   | 6°.   | 7°.   | 8°.   | 9°.   | Diff. |
|-----|-------|-------|-------|-------|-------|-------|
| 736 | 95098 | 94756 | 94417 | 94081 | 93747 | 337   |
| 7   | 227   | 885   | 545   | 208   | 874   | 337   |
| 8   | 356   | 95014 | 674   | 336   | 94001 | 337   |
| 9   | 485   | 142   | 802   | 464   | 129   | 338   |
| 740 | 614   | 271   | 930   | 592   | 256   | 338   |
| 1   | 744   | 400   | 95059 | 720   | 383   | 339   |
| 2   | 873   | 529   | 187   | 848   | 511   | 339   |
| 3   | 96002 | 657   | 315   | 975   | 638   | 340   |
| 4   | 131   | 786   | 443   | 95103 | 766   | 340   |
| 5   | 260   | 915   | 572   | 231   | 893   | 341   |
| 6   | 390   | 96044 | 700   | 359   | 95020 | 341   |
| 7   | 519   | 172   | 828   | 487   | 148   | 342   |
| 8   | 648   | 301   | 957   | 615   | 275   | 342   |
| 9   | 777   | 430   | 96085 | 742   | 402   | 342   |
| 750 | 906   | 559   | 213   | 870   | 530   | 343   |
| 1   | 97036 | 687   | 341   | 998   | 657   | 343   |
| 2   | 165   | 816   | 470   | 96126 | 784   | 344   |
| 3   | 294   | 945   | 598   | 254   | 912   | 344   |
| 4   | 423   | 97074 | 726   | 382   | 96039 | 345   |
| 5   | 553   | 202   | 855   | 509   | 167   | 345   |
| 6   | 682   | 331   | 983   | 637   | 294   | 346   |
| 7   | 811   | 460   | 97111 | 765   | 421   | 346   |
| 8   | 940   | 589   | 239   | 893   | 549   | 347   |
| 9   | 98069 | 717   | 368   | 97021 | 676   | 347   |
| 760 | 199   | 846   | 496   | 148   | 803   | 348   |
| 1   | 328   | 975   | 624   | 276   | 931   | 348   |
| 2   | 457   | 98103 | 753   | 404   | 97058 | 348   |
| 3   | 586   | 232   | 881   | 532   | 186   | 349   |
| 4   | 715   | 361   | 98009 | 660   | 315   | 349   |
| 5   | 845   | 490   | 137   | 788   | 440   | 350   |
| 6   | 974   | 618   | 266   | 915   | 568   | 350   |
| 7   | 99103 | 747   | 394   | 98043 | 695   | 351   |
| 8   | 232   | 876   | 522   | 171   | 822   | 351   |
| 9   | 361   | 99005 | 651   | 299   | 950   | 352   |
| 770 | 491   | 133   | 779   | 427   | 98077 | 352   |

| Diff. | .1. | .2. | .3. | .4. | .5. | .6. | .7. | .8. | .9. |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 128   | 13  | 26  | 38  | 51  | 64  | 77  | 90  | 102 | 115 |
| 340   | 34  | 68  | 102 | 136 | 170 | 204 | 238 | 272 | 306 |
| 343   | 34  | 69  | 103 | 137 | 171 | 206 | 240 | 274 | 309 |
| 346   | 35  | 69  | 104 | 138 | 173 | 208 | 242 | 277 | 311 |
| 349   | 35  | 70  | 105 | 140 | 174 | 209 | 244 | 279 | 314 |
| 352   | 35  | 70  | 106 | 141 | 176 | 211 | 246 | 282 | 317 |
| 355   | 35  | 71  | 106 | 142 | 177 | 213 | 248 | 284 | 319 |

|     | 10°.  | 11°.  | 12°.  | 13°.  | 14°.  | Diff. |
|-----|-------|-------|-------|-------|-------|-------|
| 701 | 88972 | 88659 | 88347 | 88038 | 87730 | 309   |
| 2   | 89099 | 785   | 473   | 163   | 856   | 310   |
| 3   | 226   | 912   | 599   | 289   | 981   | 310   |
| 4   | 353   | 89038 | 725   | 414   | 88106 | 311   |
| 5   | 480   | 165   | 851   | 540   | 231   | 311   |
| 6   | 607   | 291   | 977   | 666   | 356   | 312   |
| 7   | 734   | 418   | 89103 | 791   | 481   | 312   |
| 8   | 861   | 544   | 229   | 917   | 607   | 312   |
| 9   | 988   | 670   | 355   | 89042 | 732   | 313   |
| 710 | 90115 | 797   | 481   | 168   | 857   | 313   |
| 1   | 242   | 923   | 607   | 294   | 982   | 314   |
| 2   | 369   | 90050 | 733   | 419   | 89107 | 314   |
| 3   | 495   | 176   | 859   | 545   | 232   | 315   |
| 4   | 622   | 303   | 985   | 670   | 357   | 315   |
| 5   | 749   | 429   | 90112 | 796   | 483   | 316   |
| 6   | 876   | 556   | 238   | 922   | 608   | 316   |
| 7   | 91003 | 682   | 364   | 90047 | 733   | 316   |
| 8   | 130   | 809   | 490   | 173   | 858   | 317   |
| 9   | 257   | 935   | 616   | 298   | 983   | 317   |
| 720 | 384   | 91062 | 742   | 424   | 90108 | 318   |
| 1   | 511   | 188   | 868   | 549   | 233   | 318   |
| 2   | 638   | 315   | 994   | 675   | 359   | 319   |
| 3   | 765   | 441   | 91120 | 801   | 484   | 319   |
| 4   | 892   | 568   | 246   | 926   | 609   | 320   |
| 5   | 92019 | 694   | 372   | 91052 | 734   | 320   |
| 6   | 145   | 821   | 498   | 177   | 859   | 320   |
| 7   | 272   | 947   | 524   | 303   | 984   | 321   |
| 8   | 399   | 92073 | 750   | 429   | 91110 | 321   |
| 9   | 526   | 200   | 876   | 554   | 235   | 322   |
| 730 | 653   | 326   | 92002 | 680   | 360   | 322   |
| 1   | 780   | 453   | 128   | 805   | 485   | 323   |
| 2   | 907   | 579   | 254   | 931   | 610   | 323   |
| 3   | 93034 | 706   | 380   | 92057 | 735   | 323   |
| 4   | 161   | 832   | 506   | 182   | 860   | 324   |
| 5   | 288   | 959   | 632   | 308   | 986   | 324   |

| Diff. | .1. | .2. | .3. | .4. | .5. | .6. | .7. | .8. | .9. |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 126   | 13  | 25  | 38  | 50  | 63  | 76  | 88  | 101 | 113 |
| 310   | 31  | 62  | 93  | 124 | 155 | 186 | 217 | 248 | 279 |
| 313   | 31  | 63  | 94  | 125 | 156 | 188 | 219 | 250 | 282 |
| 316   | 32  | 63  | 95  | 126 | 158 | 190 | 221 | 253 | 284 |
| 319   | 32  | 64  | 96  | 128 | 159 | 191 | 223 | 255 | 287 |
| 322   | 32  | 64  | 97  | 129 | 161 | 193 | 225 | 258 | 290 |
| 325   | 32  | 65  | 97  | 130 | 162 | 195 | 227 | 260 | 292 |

|     | 10°.  | 11°.  | 12°.  | 13°.  | 14°.  | Diff. |
|-----|-------|-------|-------|-------|-------|-------|
| 736 | 93415 | 93085 | 92758 | 92433 | 92111 | 325   |
| 7   | 542   | 212   | 884   | 559   | 236   | 325   |
| 8   | 669   | 338   | 93010 | 684   | 361   | 326   |
| 9   | 795   | 465   | 136   | 810   | 486   | 326   |
| 740 | 922   | 591   | 262   | 936   | 611   | 327   |
| 1   | 94049 | 718   | 388   | 93061 | 736   | 327   |
| 2   | 176   | 844   | 514   | 187   | 862   | 327   |
| 3   | 303   | 971   | 640   | 312   | 987   | 328   |
| 4   | 430   | 94099 | 766   | 438   | 93112 | 328   |
| 5   | 557   | 224   | 892   | 564   | 237   | 329   |
| 6   | 684   | 350   | 94018 | 689   | 362   | 329   |
| 7   | 811   | 476   | 144   | 815   | 487   | 330   |
| 8   | 938   | 603   | 271   | 940   | 613   | 330   |
| 9   | 95065 | 729   | 397   | 94066 | 738   | 331   |
| 750 | 192   | 856   | 523   | 192   | 863   | 331   |
| 1   | 319   | 982   | 649   | 317   | 988   | 331   |
| 2   | 445   | 95109 | 775   | 443   | 94113 | 332   |
| 3   | 572   | 235   | 901   | 568   | 238   | 332   |
| 4   | 699   | 362   | 95027 | 694   | 363   | 333   |
| 5   | 826   | 488   | 153   | 820   | 489   | 333   |
| 6   | 953   | 615   | 279   | 945   | 614   | 334   |
| 7   | 96080 | 741   | 405   | 95071 | 739   | 334   |
| 8   | 207   | 868   | 531   | 196   | 864   | 335   |
| 9   | 334   | 994   | 657   | 322   | 989   | 335   |
| 760 | 461   | 96121 | 783   | 447   | 95114 | 335   |
| 1   | 588   | 247   | 909   | 573   | 240   | 336   |
| 2   | 715   | 374   | 96035 | 699   | 365   | 336   |
| 3   | 842   | 500   | 161   | 824   | 490   | 337   |
| 4   | 969   | 627   | 287   | 950   | 615   | 337   |
| 5   | 97095 | 753   | 413   | 96075 | 740   | 338   |
| 6   | 222   | 880   | 539   | 201   | 865   | 338   |
| 7   | 349   | 97006 | 665   | 327   | 990   | 339   |
| 8   | 476   | 132   | 791   | 452   | 96116 | 339   |
| 9   | 603   | 259   | 917   | 578   | 241   | 339   |
| 770 | 730   | 385   | 97043 | 703   | 366   | 340   |

| Diff. | .1. | .2. | .3. | .4. | .5. | .6. | .7. | .8. | .9. |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 126   | 13  | 25  | 38  | 50  | 63  | 76  | 88  | 101 | 113 |
| 328   | 33  | 66  | 98  | 131 | 164 | 197 | 230 | 262 | 295 |
| 331   | 33  | 66  | 99  | 132 | 165 | 199 | 232 | 265 | 298 |
| 334   | 33  | 67  | 100 | 134 | 167 | 200 | 234 | 267 | 301 |
| 337   | 34  | 67  | 101 | 135 | 168 | 202 | 236 | 270 | 303 |
| 340   | 34  | 68  | 102 | 136 | 170 | 204 | 238 | 272 | 306 |
| 343   | 34  | 69  | 103 | 137 | 171 | 206 | 240 | 274 | 309 |

|     | 15°.  | 16°.  | 17°.  | 18°.  | 19°.  | Diff. |
|-----|-------|-------|-------|-------|-------|-------|
| 701 | 87425 | 87122 | 86822 | 86523 | 86226 | 299   |
| 2   | 550   | 247   | 945   | 646   | 349   | 299   |
| 3   | 675   | 371   | 87069 | 770   | 472   | 300   |
| 4   | 800   | 495   | 193   | 893   | 595   | 300   |
| 5   | 924   | 620   | 317   | 87016 | 718   | 301   |
| 6   | 88049 | 744   | 441   | 140   | 841   | 301   |
| 7   | 174   | 868   | 565   | 263   | 964   | 301   |
| 8   | 298   | 992   | 688   | 387   | 87087 | 302   |
| 9   | 423   | 88117 | 812   | 510   | 210   | 302   |
| 710 | 548   | 241   | 936   | 634   | 333   | 303   |
| 1   | 673   | 365   | 88060 | 757   | 456   | 303   |
| 2   | 797   | 490   | 184   | 880   | 579   | 304   |
| 3   | 922   | 614   | 308   | 88004 | 702   | 304   |
| 4   | 89047 | 738   | 432   | 127   | 825   | 304   |
| 5   | 171   | 862   | 555   | 251   | 948   | 305   |
| 6   | 296   | 987   | 679   | 374   | 88071 | 305   |
| 7   | 421   | 89111 | 803   | 498   | 194   | 306   |
| 8   | 546   | 235   | 927   | 621   | 317   | 306   |
| 9   | 670   | 360   | 89051 | 744   | 440   | 306   |
| 720 | 795   | 484   | 175   | 868   | 563   | 307   |
| 1   | 920   | 608   | 299   | 991   | 686   | 307   |
| 2   | 90044 | 732   | 422   | 89115 | 809   | 308   |
| 3   | 169   | 857   | 546   | 238   | 932   | 308   |
| 4   | 294   | 981   | 670   | 362   | 89055 | 309   |
| 5   | 419   | 90105 | 794   | 485   | 178   | 309   |
| 6   | 543   | 229   | 918   | 608   | 301   | 309   |
| 7   | 668   | 354   | 90042 | 732   | 424   | 310   |
| 8   | 793   | 478   | 166   | 855   | 547   | 310   |
| 9   | 917   | 602   | 289   | 979   | 670   | 311   |
| 730 | 91042 | 727   | 413   | 90102 | 793   | 311   |
| 1   | 167   | 851   | 537   | 226   | 916   | 312   |
| 2   | 292   | 975   | 661   | 349   | 90039 | 312   |
| 3   | 416   | 91099 | 785   | 472   | 162   | 312   |
| 4   | 541   | 224   | 909   | 596   | 285   | 313   |
| 5   | 666   | 348   | 91033 | 719   | 408   | 313   |

| Diff. | .1. | .2. | .3. | .4. | .5. | .6. | .7. | .8. | .9. |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 124   | 12  | 25  | 37  | 50  | 62  | 74  | 87  | 99  | 112 |
| 298   | 30  | 60  | 89  | 119 | 149 | 179 | 209 | 238 | 268 |
| 301   | 30  | 60  | 90  | 120 | 150 | 181 | 211 | 241 | 271 |
| 304   | 30  | 61  | 91  | 122 | 152 | 182 | 213 | 243 | 274 |
| 307   | 31  | 61  | 92  | 123 | 153 | 184 | 215 | 246 | 276 |
| 310   | 31  | 62  | 93  | 124 | 155 | 186 | 217 | 248 | 279 |
| 313   | 31  | 63  | 94  | 125 | 156 | 188 | 219 | 250 | 282 |

|     | 15°.  | 16°.  | 17°.  | 18°.  | 19°.  | Diff. |
|-----|-------|-------|-------|-------|-------|-------|
| 736 | 91790 | 91472 | 91156 | 90843 | 90531 | 314   |
| 7   | 915   | 597   | 280   | 966   | 654   | 314   |
| 8   | 92040 | 721   | 404   | 91090 | 777   | 315   |
| 9   | 165   | 845   | 528   | 213   | 900   | 315   |
| 740 | 289   | 969   | 652   | 336   | 91023 | 315   |
| 1   | 414   | 92094 | 776   | 460   | 146   | 316   |
| 2   | 539   | 218   | 900   | 583   | 269   | 316   |
| 3   | 663   | 342   | 92023 | 707   | 392   | 317   |
| 4   | 788   | 467   | 147   | 830   | 515   | 317   |
| 5   | 913   | 591   | 271   | 954   | 638   | 318   |
| 6   | 93038 | 715   | 395   | 92077 | 761   | 318   |
| 7   | 162   | 839   | 519   | 200   | 884   | 318   |
| 8   | 287   | 964   | 643   | 324   | 92007 | 319   |
| 9   | 412   | 93088 | 767   | 447   | 130   | 319   |
| 750 | 536   | 212   | 890   | 571   | 253   | 320   |
| 1   | 661   | 337   | 93014 | 694   | 376   | 320   |
| 2   | 786   | 461   | 138   | 818   | 499   | 321   |
| 3   | 911   | 585   | 262   | 941   | 622   | 321   |
| 4   | 94035 | 709   | 386   | 93064 | 745   | 321   |
| 5   | 160   | 834   | 510   | 188   | 868   | 322   |
| 6   | 285   | 958   | 633   | 311   | 991   | 322   |
| 7   | 409   | 94082 | 757   | 435   | 93114 | 323   |
| 8   | 534   | 207   | 881   | 558   | 237   | 323   |
| 9   | 659   | 331   | 94005 | 682   | 360   | 324   |
| 760 | 784   | 455   | 129   | 805   | 483   | 324   |
| 1   | 908   | 579   | 253   | 928   | 606   | 324   |
| 2   | 95033 | 704   | 377   | 94052 | 729   | 325   |
| 3   | 158   | 828   | 500   | 175   | 852   | 325   |
| 4   | 282   | 952   | 624   | 299   | 975   | 326   |
| 5   | 407   | 95077 | 748   | 422   | 94098 | 326   |
| 6   | 532   | 201   | 872   | 546   | 221   | 327   |
| 7   | 657   | 325   | 996   | 669   | 344   | 327   |
| 8   | 781   | 449   | 95120 | 792   | 467   | 327   |
| 9   | 906   | 574   | 244   | 916   | 590   | 328   |
| 770 | 96031 | 698   | 367   | 95039 | 713   | 328   |

| Diff. | .1. | .2. | .3. | .4. | .5. | .6. | .7. | .8. | .9. |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 124   | 12  | 25  | 37  | 50  | 62  | 74  | 87  | 99  | 112 |
| 316   | 32  | 63  | 95  | 126 | 158 | 190 | 221 | 253 | 284 |
| 319   | 32  | 64  | 96  | 128 | 159 | 191 | 223 | 255 | 287 |
| 322   | 32  | 64  | 97  | 129 | 161 | 193 | 225 | 258 | 290 |
| 325   | 32  | 65  | 97  | 130 | 162 | 195 | 227 | 260 | 292 |
| 328   | 33  | 66  | 98  | 131 | 164 | 197 | 230 | 262 | 295 |
| 331   | 33  | 66  | 99  | 132 | 165 | 199 | 232 | 265 | 298 |



|       | 20°.  | 21°.  | 22°.  | 23°.  | 24°.  | Diff. |     |     |     |
|-------|-------|-------|-------|-------|-------|-------|-----|-----|-----|
| 701   | 85931 | 85639 | 85348 | 85059 | 84772 | 289   |     |     |     |
| 2     | 86054 | 761   | 469   | 180   | 893   | 289   |     |     |     |
| 3     | 176   | 883   | 591   | 302   | 85014 | 290   |     |     |     |
| 4     | 299   | 86005 | 713   | 423   | 135   | 290   |     |     |     |
| 5     | 422   | 127   | 835   | 544   | 256   | 290   |     |     |     |
| 6     | 544   | 249   | 956   | 666   | 377   | 291   |     |     |     |
| 7     | 667   | 372   | 86078 | 787   | 498   | 291   |     |     |     |
| 8     | 789   | 494   | 200   | 908   | 619   | 292   |     |     |     |
| 9     | 912   | 616   | 322   | 86030 | 740   | 292   |     |     |     |
| 710   | 87034 | 738   | 443   | 151   | 860   | 292   |     |     |     |
| 1     | 157   | 860   | 565   | 272   | 981   | 293   |     |     |     |
| 2     | 280   | 982   | 687   | 394   | 86102 | 283   |     |     |     |
| 3     | 402   | 87105 | 809   | 515   | 223   | 294   |     |     |     |
| 4     | 525   | 227   | 931   | 636   | 344   | 294   |     |     |     |
| 5     | 647   | 349   | 87052 | 758   | 465   | 295   |     |     |     |
| 6     | 770   | 471   | 174   | 879   | 586   | 295   |     |     |     |
| 7     | 892   | 593   | 296   | 87000 | 707   | 295   |     |     |     |
| 8     | 88015 | 715   | 418   | 122   | 828   | 296   |     |     |     |
| 9     | 138   | 838   | 539   | 243   | 949   | 296   |     |     |     |
| 720   | 260   | 960   | 661   | 364   | 87070 | 297   |     |     |     |
| 1     | 383   | 88082 | 783   | 486   | 191   | 297   |     |     |     |
| 2     | 505   | 204   | 905   | 607   | 312   | 297   |     |     |     |
| 3     | 628   | 326   | 88026 | 728   | 433   | 298   |     |     |     |
| 4     | 751   | 448   | 148   | 850   | 554   | 298   |     |     |     |
| 5     | 873   | 571   | 270   | 971   | 674   | 299   |     |     |     |
| 6     | 996   | 693   | 392   | 88092 | 795   | 299   |     |     |     |
| 7     | 89118 | 815   | 513   | 214   | 916   | 299   |     |     |     |
| 8     | 241   | 937   | 635   | 335   | 88037 | 300   |     |     |     |
| 9     | 364   | 89059 | 757   | 456   | 158   | 300   |     |     |     |
| 730   | 486   | 181   | 879   | 578   | 279   | 301   |     |     |     |
| 1     | 609   | 304   | 89000 | 699   | 400   | 301   |     |     |     |
| 2     | 731   | 426   | 122   | 820   | 521   | 302   |     |     |     |
| 3     | 854   | 548   | 244   | 942   | 642   | 302   |     |     |     |
| 4     | 976   | 670   | 366   | 89063 | 763   | 302   |     |     |     |
| 5     | 90099 | 792   | 487   | 184   | 884   | 303   |     |     |     |
|       |       |       |       |       |       |       |     |     |     |
| Diff. | ·1.   | ·2.   | ·3.   | ·4.   | ·5.   | ·6.   | ·7. | ·8. | ·9. |
| 122   | 12    | 24    | 37    | 49    | 61    | 73    | 85  | 98  | 110 |
| 286   | 29    | 57    | 86    | 114   | 143   | 172   | 200 | 229 | 257 |
| 289   | 29    | 58    | 87    | 116   | 144   | 173   | 202 | 231 | 260 |
| 292   | 29    | 58    | 88    | 117   | 146   | 175   | 204 | 234 | 263 |
| 295   | 29    | 59    | 88    | 118   | 147   | 177   | 206 | 236 | 265 |
| 298   | 30    | 60    | 89    | 119   | 149   | 179   | 209 | 238 | 268 |
| 301   | 30    | 60    | 90    | 120   | 150   | 181   | 211 | 241 | 271 |

|     | 20°.  | 21°.  | 22°.  | 23°.  | 24°.  | Diff. |
|-----|-------|-------|-------|-------|-------|-------|
| 736 | 90222 | 89914 | 89609 | 89306 | 89005 | 303   |
| 7   | 344   | 90036 | 731   | 427   | 126   | 304   |
| 8   | 467   | 159   | 853   | 548   | 247   | 304   |
| 9   | 589   | 281   | 974   | 670   | 367   | 304   |
| 740 | 712   | 403   | 90096 | 791   | 488   | 305   |
| 1   | 835   | 525   | 218   | 913   | 609   | 305   |
| 2   | 957   | 647   | 340   | 90034 | 730   | 306   |
| 3   | 91080 | 769   | 461   | 155   | 851   | 306   |
| 4   | 202   | 892   | 583   | 277   | 972   | 306   |
| 5   | 325   | 91014 | 705   | 398   | 90093 | 307   |
| 6   | 447   | 136   | 827   | 519   | 214   | 307   |
| 7   | 570   | 258   | 948   | 641   | 335   | 308   |
| 8   | 693   | 380   | 91070 | 762   | 456   | 308   |
| 9   | 815   | 502   | 192   | 883   | 577   | 309   |
| 750 | 938   | 625   | 314   | 91005 | 698   | 309   |
| 1   | 92060 | 747   | 435   | 126   | 819   | 309   |
| 2   | 183   | 869   | 557   | 247   | 940   | 310   |
| 3   | 306   | 991   | 679   | 369   | 91061 | 310   |
| 4   | 428   | 92113 | 801   | 490   | 181   | 311   |
| 5   | 551   | 235   | 922   | 611   | 302   | 311   |
| 6   | 673   | 358   | 92044 | 733   | 423   | 311   |
| 7   | 796   | 480   | 166   | 854   | 544   | 312   |
| 8   | 918   | 602   | 288   | 975   | 665   | 312   |
| 9   | 93041 | 723   | 409   | 92097 | 786   | 313   |
| 760 | 164   | 846   | 531   | 218   | 907   | 313   |
| 1   | 286   | 968   | 653   | 339   | 92028 | 313   |
| 2   | 409   | 93091 | 775   | 461   | 149   | 314   |
| 3   | 531   | 213   | 896   | 582   | 270   | 314   |
| 4   | 654   | 335   | 93018 | 703   | 391   | 315   |
| 5   | 777   | 457   | 140   | 825   | 512   | 315   |
| 6   | 899   | 579   | 262   | 946   | 633   | 316   |
| 7   | 94022 | 701   | 383   | 93067 | 754   | 316   |
| 8   | 144   | 824   | 505   | 189   | 874   | 316   |
| 9   | 267   | 946   | 627   | 310   | 995   | 317   |
| 770 | 389   | 94068 | 749   | 431   | 93116 | 317   |

| Diff. | .1. | .2. | .3. | .4. | .5. | .6. | .7. | .8. | .9. |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 122   | 12  | 24  | 37  | 49  | 61  | 73  | 85  | 98  | 110 |
| 304   | 30  | 61  | 91  | 122 | 152 | 182 | 213 | 243 | 274 |
| 307   | 31  | 61  | 92  | 123 | 153 | 184 | 215 | 246 | 276 |
| 310   | 31  | 62  | 93  | 124 | 155 | 186 | 217 | 248 | 279 |
| 313   | 31  | 63  | 94  | 125 | 156 | 188 | 219 | 250 | 282 |
| 316   | 32  | 63  | 95  | 126 | 158 | 190 | 221 | 253 | 284 |
| 319   | 32  | 64  | 96  | 128 | 159 | 191 | 223 | 255 | 287 |

|       | 25°.  | 26°.  | 27°.  | 28°.  | 29°.  | Diff. |     |     |     |
|-------|-------|-------|-------|-------|-------|-------|-----|-----|-----|
| 701   | 84487 | 84204 | 83923 | 83644 | 83367 | 279   |     |     |     |
| 2     | 608   | 324   | 84043 | 763   | 485   | 280   |     |     |     |
| 3     | 728   | 445   | 163   | 883   | 604   | 280   |     |     |     |
| 4     | 849   | 565   | 282   | 84002 | 723   | 280   |     |     |     |
| 5     | 969   | 685   | 402   | 121   | 842   | 281   |     |     |     |
| 6     | 85090 | 805   | 522   | 241   | 961   | 281   |     |     |     |
| 7     | 210   | 925   | 641   | 360   | 84080 | 282   |     |     |     |
| 8     | 331   | 85045 | 761   | 479   | 199   | 282   |     |     |     |
| 9     | 451   | 165   | 881   | 598   | 318   | 282   |     |     |     |
| 710   | 572   | 285   | 85001 | 718   | 437   | 283   |     |     |     |
| 1     | 692   | 405   | 120   | 837   | 556   | 283   |     |     |     |
| 2     | 813   | 526   | 240   | 956   | 675   | 284   |     |     |     |
| 3     | 934   | 646   | 360   | 85076 | 794   | 284   |     |     |     |
| 4     | 86054 | 766   | 480   | 195   | 913   | 284   |     |     |     |
| 5     | 175   | 886   | 599   | 314   | 85031 | 285   |     |     |     |
| 6     | 295   | 86006 | 719   | 434   | 150   | 285   |     |     |     |
| 7     | 416   | 126   | 839   | 553   | 269   | 286   |     |     |     |
| 8     | 536   | 246   | 958   | 672   | 388   | 286   |     |     |     |
| 9     | 657   | 366   | 86078 | 792   | 507   | 286   |     |     |     |
| 720   | 777   | 487   | 198   | 911   | 626   | 287   |     |     |     |
| 1     | 898   | 607   | 318   | 86030 | 745   | 287   |     |     |     |
| 2     | 87018 | 727   | 437   | 150   | 864   | 288   |     |     |     |
| 3     | 139   | 847   | 557   | 269   | 983   | 288   |     |     |     |
| 4     | 259   | 967   | 677   | 388   | 86102 | 288   |     |     |     |
| 5     | 380   | 87087 | 796   | 508   | 221   | 289   |     |     |     |
| 6     | 500   | 207   | 916   | 627   | 340   | 289   |     |     |     |
| 7     | 621   | 327   | 87036 | 746   | 459   | 290   |     |     |     |
| 8     | 741   | 447   | 156   | 866   | 578   | 290   |     |     |     |
| 9     | 862   | 568   | 275   | 985   | 696   | 290   |     |     |     |
| 730   | 982   | 688   | 395   | 87104 | 815   | 291   |     |     |     |
| 1     | 88103 | 808   | 515   | 224   | 934   | 291   |     |     |     |
| 2     | 223   | 928   | 634   | 343   | 87053 | 292   |     |     |     |
| 3     | 344   | 88048 | 754   | 462   | 172   | 292   |     |     |     |
| 4     | 465   | 168   | 874   | 582   | 291   | 292   |     |     |     |
| 5     | 585   | 288   | 994   | 701   | 410   | 293   |     |     |     |
| <hr/> |       |       |       |       |       |       |     |     |     |
| Diff. | .1.   | .2.   | .3.   | .4.   | .5.   | .6.   | .7. | .8. | .9. |
| 120   | 12    | 24    | 36    | 48    | 60    | 72    | 84  | 96  | 108 |
| 274   | 27    | 55    | 82    | 110   | 137   | 164   | 192 | 219 | 247 |
| 277   | 28    | 55    | 83    | 111   | 138   | 166   | 194 | 222 | 249 |
| 280   | 28    | 56    | 84    | 112   | 140   | 168   | 196 | 224 | 252 |
| 283   | 28    | 57    | 85    | 113   | 141   | 170   | 198 | 226 | 255 |
| 286   | 29    | 57    | 86    | 114   | 143   | 172   | 200 | 229 | 257 |
| 289   | 29    | 58    | 87    | 116   | 144   | 173   | 202 | 231 | 260 |

|     | 25°.  | 26°.  | 27°.  | 28°.  | 29°.  | Diff. |
|-----|-------|-------|-------|-------|-------|-------|
| 736 | 88706 | 88408 | 88113 | 87820 | 87529 | 293   |
| 7   | 826   | 529   | 233   | 939   | 648   | 294   |
| 8   | 947   | 649   | 353   | 88059 | 767   | 294   |
| 9   | 89067 | 769   | 472   | 178   | 886   | 294   |
| 740 | 188   | 889   | 592   | 297   | 88005 | 295   |
| 1   | 308   | 89009 | 712   | 417   | 124   | 295   |
| 2   | 429   | 129   | 832   | 536   | 242   | 296   |
| 3   | 549   | 249   | 951   | 655   | 361   | 296   |
| 4   | 670   | 369   | 89071 | 775   | 480   | 296   |
| 5   | 790   | 490   | 191   | 894   | 599   | 297   |
| 6   | 911   | 610   | 311   | 89013 | 718   | 297   |
| 7   | 90031 | 730   | 430   | 133   | 837   | 298   |
| 8   | 152   | 850   | 550   | 252   | 956   | 298   |
| 9   | 272   | 970   | 670   | 371   | 89075 | 298   |
| 750 | 393   | 90090 | 789   | 491   | 194   | 299   |
| 1   | 513   | 210   | 909   | 610   | 313   | 299   |
| 2   | 634   | 330   | 90029 | 729   | 432   | 300   |
| 3   | 754   | 450   | 149   | 849   | 551   | 300   |
| 4   | 875   | 571   | 268   | 968   | 670   | 300   |
| 5   | 996   | 691   | 388   | 90087 | 788   | 301   |
| 6   | 91116 | 811   | 508   | 207   | 907   | 301   |
| 7   | 237   | 931   | 627   | 326   | 90026 | 302   |
| 8   | 357   | 91051 | 747   | 445   | 145   | 302   |
| 9   | 478   | 171   | 867   | 565   | 264   | 302   |
| 760 | 598   | 291   | 987   | 684   | 383   | 303   |
| 1   | 719   | 411   | 91106 | 803   | 502   | 303   |
| 2   | 839   | 532   | 226   | 923   | 621   | 304   |
| 3   | 960   | 652   | 346   | 91042 | 740   | 304   |
| 4   | 92080 | 772   | 465   | 161   | 859   | 304   |
| 5   | 201   | 892   | 585   | 280   | 978   | 305   |
| 6   | 321   | 92012 | 705   | 400   | 91097 | 305   |
| 7   | 442   | 132   | 825   | 519   | 216   | 306   |
| 8   | 562   | 252   | 944   | 638   | 335   | 306   |
| 9   | 683   | 372   | 92064 | 758   | 453   | 306   |
| 770 | 803   | 493   | 184   | 877   | 572   | 307   |

| Diff. | .1. | .2. | .3. | .4. | .5. | .6. | .7. | .8. | .9. |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 120   | 12  | 24  | 36  | 48  | 60  | 72  | 84  | 96  | 108 |
| 292   | 29  | 58  | 88  | 117 | 146 | 175 | 204 | 234 | 263 |
| 295   | 29  | 59  | 88  | 118 | 147 | 177 | 206 | 236 | 265 |
| 298   | 30  | 60  | 89  | 119 | 149 | 179 | 209 | 238 | 268 |
| 301   | 30  | 60  | 90  | 120 | 150 | 181 | 211 | 241 | 271 |
| 304   | 30  | 61  | 91  | 122 | 152 | 182 | 213 | 243 | 274 |
| 307   | 31  | 61  | 92  | 123 | 153 | 184 | 215 | 246 | 276 |

## Correction of Barometer Readings.

The reading of the barometer requires to be corrected (i) for capillary depression of the mercury if the tube is less than about 15 mm. in bore, (ii) for temperature of the mercury column and scale, (iii) for variation of "gravity" from the standard owing to difference in latitude from  $45^\circ$  or to height above sea-level. Corrections (ii) and (iii) are necessary, since standard gravity, to which condition densities of gases are always reduced for comparison, signifies that at lat.  $45^\circ$  and sea-level, the mercury column being at  $0^\circ\text{C}$ .

### REDUCTION OF BAROMETRIC READINGS TO $0^\circ\text{C}$ .

The corrected height  $B_0 = B_t \left\{ 1 - \frac{(\beta - \alpha)t}{1 + \beta t} \right\}$  where  $B_t$  is the reading observed at the temperature  $t^\circ\text{C}$ ., corrected if necessary for capillary depression of the mercury,  $\beta$  is the coefficient of cubical expansion of mercury, and  $\alpha$  the coefficient of linear expansion of the scale. The table below gives values of the correction  $B_t \times \frac{(\beta - \alpha)t}{1 + \beta t}$  to be subtracted from  $B_t$  for barometers with a brass scale, assuming  $\beta = 1818 \times 10^{-7}$  and  $\alpha = 184 \times 10^{-7}$  (*International Meteorological Tables*, 1890). For barometers with glass scales, for which  $\alpha = 85 \times 10^{-7}$ , the correction is greater by 6.1% than the value given for brass scales.  $B_t$  and the correction are in mm.

| Uncorrected height. |      |      |      |      |      |      |      |      |      |      |
|---------------------|------|------|------|------|------|------|------|------|------|------|
| $t^\circ\text{C}$ . | 700. | 710. | 720. | 730. | 740. | 750. | 760. | 770. | 780. | 790. |
| 1                   | .11  | .12  | .12  | .12  | .12  | .12  | .12  | .13  | .13  | .13  |
| 2                   | .23  | .23  | .24  | .24  | .24  | .25  | .25  | .25  | .25  | .26  |
| 3                   | .34  | .35  | .35  | .36  | .36  | .37  | .37  | .38  | .38  | .39  |
| 4                   | .46  | .46  | .47  | .48  | .48  | .49  | .50  | .50  | .51  | .52  |
| 5                   | .57  | .58  | .59  | .60  | .60  | .61  | .62  | .63  | .64  | .64  |
| 6                   | .69  | .70  | .71  | .71  | .72  | .73  | .74  | .75  | .76  | .77  |
| 7                   | .80  | .81  | .82  | .83  | .85  | .86  | .87  | .88  | .89  | .90  |
| 8                   | .91  | .93  | .94  | .95  | .97  | .98  | .99  | 1.01 | 1.02 | 1.03 |
| 9                   | 1.03 | 1.04 | 1.06 | 1.07 | 1.09 | 1.10 | 1.12 | 1.13 | 1.15 | 1.16 |
| 10                  | 1.14 | 1.16 | 1.17 | 1.19 | 1.21 | 1.22 | 1.24 | 1.26 | 1.27 | 1.29 |
| 11                  | 1.26 | 1.27 | 1.29 | 1.31 | 1.33 | 1.35 | 1.36 | 1.38 | 1.40 | 1.42 |
| 12                  | 1.37 | 1.39 | 1.41 | 1.43 | 1.45 | 1.47 | 1.49 | 1.51 | 1.53 | 1.55 |
| 13                  | 1.48 | 1.50 | 1.53 | 1.55 | 1.57 | 1.59 | 1.61 | 1.63 | 1.65 | 1.67 |
| 14                  | 1.60 | 1.62 | 1.64 | 1.67 | 1.69 | 1.71 | 1.73 | 1.76 | 1.78 | 1.80 |
| 15                  | 1.71 | 1.74 | 1.76 | 1.78 | 1.81 | 1.83 | 1.86 | 1.88 | 1.91 | 1.93 |

| $t^{\circ}\text{C.}$ | Uncorrected height. |      |      |      |      |      |      |      |      |      |
|----------------------|---------------------|------|------|------|------|------|------|------|------|------|
|                      | 700.                | 710. | 720. | 730. | 740. | 750. | 760. | 770. | 780. | 790. |
| 16                   | 1.82                | 1.85 | 1.88 | 1.90 | 1.93 | 1.96 | 1.98 | 2.01 | 2.03 | 2.06 |
| 17                   | 1.94                | 1.97 | 1.99 | 2.02 | 2.05 | 2.08 | 2.10 | 2.13 | 2.16 | 2.19 |
| 18                   | 2.05                | 2.08 | 2.11 | 2.14 | 2.17 | 2.20 | 2.23 | 2.26 | 2.29 | 2.32 |
| 19                   | 2.17                | 2.20 | 2.23 | 2.26 | 2.29 | 2.32 | 2.35 | 2.38 | 2.41 | 2.44 |
| 20                   | 2.28                | 2.31 | 2.34 | 2.38 | 2.41 | 2.44 | 2.47 | 2.51 | 2.54 | 2.57 |
| 21                   | 2.39                | 2.43 | 2.46 | 2.50 | 2.53 | 2.56 | 2.60 | 2.63 | 2.67 | 2.70 |
| 22                   | 2.51                | 2.54 | 2.58 | 2.61 | 2.65 | 2.69 | 2.72 | 2.76 | 2.79 | 2.83 |
| 23                   | 2.62                | 2.66 | 2.69 | 2.73 | 2.77 | 2.81 | 2.84 | 2.88 | 2.92 | 2.96 |
| 24                   | 2.73                | 2.77 | 2.81 | 2.85 | 2.89 | 2.93 | 2.97 | 3.01 | 3.05 | 3.08 |
| 25                   | 2.85                | 2.89 | 2.93 | 2.97 | 3.01 | 3.05 | 3.09 | 3.13 | 3.17 | 3.21 |
| 26                   | 2.96                | 3.00 | 3.04 | 3.09 | 3.13 | 3.17 | 3.21 | 3.26 | 3.30 | 3.34 |
| 27                   | 3.07                | 3.12 | 3.16 | 3.20 | 3.25 | 3.29 | 3.34 | 3.38 | 3.42 | 3.47 |
| 28                   | 3.19                | 3.23 | 3.28 | 3.32 | 3.37 | 3.41 | 3.46 | 3.51 | 3.55 | 3.60 |
| 29                   | 3.30                | 3.35 | 3.39 | 3.44 | 3.49 | 3.54 | 3.58 | 3.63 | 3.68 | 3.72 |
| 30                   | 3.41                | 3.46 | 3.51 | 3.56 | 3.61 | 3.66 | 3.71 | 3.75 | 3.80 | 3.85 |

### REDUCTION OF BAROMETRIC READINGS TO LAT. $45^{\circ}$ AND SEA-LEVEL.

The standard value of gravity is that at lat.  $45^{\circ}$  and sea-level. The corrections given below in mm. are to be subtracted from  $B_0$  for latitudes  $0^{\circ}$ — $45^{\circ}$ , and added for latitudes  $45^{\circ}$  to  $90^{\circ}$ . The correction for height above sea-level is to be subtracted from  $B_0$  after it has been reduced to lat.  $45^{\circ}$ .

| $B_0$ | Latitude.                        |                                  |                                  |                                  | Height above sea-level, metres. |      |      |      |       |
|-------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------------|------|------|------|-------|
|       | $25^{\circ}$ .<br>$65^{\circ}$ . | $30^{\circ}$ .<br>$60^{\circ}$ . | $35^{\circ}$ .<br>$55^{\circ}$ . | $40^{\circ}$ .<br>$50^{\circ}$ . | 200.                            | 400. | 600. | 800. | 1000. |
| 680   | 1.13                             | 0.88                             | 0.60                             | 0.31                             | 0.03                            | 0.05 | 0.08 | 0.11 | 0.13  |
| 700   | 1.17                             | 0.91                             | 0.62                             | 0.31                             | 0.03                            | 0.05 | 0.08 | 0.11 | 0.14  |
| 720   | 1.20                             | 0.93                             | 0.64                             | 0.32                             | 0.03                            | 0.06 | 0.08 | 0.11 | 0.14  |
| 740   | 1.23                             | 0.96                             | 0.66                             | 0.33                             | 0.03                            | 0.06 | 0.09 | 0.12 | —     |
| 760   | 1.27                             | 0.98                             | 0.67                             | 0.34                             | 0.03                            | 0.06 | —    | —    | —     |
| 780   | 1.30                             | 1.01                             | 0.69                             | 0.35                             | 0.03                            | —    | —    | —    | —     |

The approximate latitudes of London and Cardiff are  $51.5^{\circ}$  ( $0.45$ ), Birmingham and Aberystwyth  $52.5^{\circ}$  ( $0.50$ ), Manchester and Sheffield  $53.5^{\circ}$  ( $0.57$ ), Newcastle  $55^{\circ}$ , Glasgow  $56^{\circ}$  ( $0.74$ ), the latitude corrections for which are, for  $B_0=760$ , the figures given in brackets.

# CAPILLARY DEPRESSION OF MERCURY IN A GLASS TUBE.

(Mendeleeff and Gutkowski; Kohlrausch.)

The depressions given are in mms. and are to be added to the observed reading of the barometer if the lower reservoir has a diameter of 25 mms. or more. The correction varies with the cleanliness of the mercury and glass.

| Diam.<br>mm. | Height of meniscus in mm. |      |      |      |      |      |      |      |
|--------------|---------------------------|------|------|------|------|------|------|------|
|              | 0.4                       | 0.6  | 0.8  | 1.0  | 1.2  | 1.4  | 1.6  | 1.8  |
| 4            | 0.83                      | 1.22 | 1.54 | 1.98 | 2.37 | —    | —    | —    |
| 5            | 0.47                      | 0.65 | 0.86 | 1.19 | 1.45 | 1.80 | —    | —    |
| 6            | 0.27                      | 0.41 | 0.56 | 0.78 | 0.98 | 1.21 | 1.43 | —    |
| 7            | 0.17                      | 0.28 | 0.40 | 0.53 | 0.67 | 0.82 | 0.97 | 1.13 |
| 8            | —                         | 0.20 | 0.29 | 0.38 | 0.46 | 0.56 | 0.65 | 0.77 |
| 9            | —                         | 0.15 | 0.21 | 0.28 | 0.33 | 0.40 | 0.46 | 0.52 |
| 10           | —                         | —    | 0.15 | 0.20 | 0.25 | 0.29 | 0.33 | 0.37 |
| 11           | —                         | —    | 0.10 | 0.14 | 0.18 | 0.21 | 0.24 | 0.27 |
| 12           | —                         | —    | 0.07 | 0.10 | 0.13 | 0.15 | 0.18 | 0.19 |
| 13           | —                         | —    | 0.04 | 0.07 | 0.10 | 0.12 | 0.13 | 0.14 |

## Vapour Pressures.

Saturation pressure of water vapour below 0°C., in mm. of mercury at 0°C. and lat. 45° (Scheel and Heuse, *Ann. d. Phys.*, 1909, 29, 723).

| °C. | Over<br>ice. | Over<br>water. | °C. | Over<br>ice. | Over<br>water. | °C. | Over<br>ice. |
|-----|--------------|----------------|-----|--------------|----------------|-----|--------------|
| 0   | 4.579        | 4.579          | -10 | 1.963        | 2.160          | -20 | 0.784        |
| -1  | 4.219        | 4.259          | -11 | 1.797        | 1.996          | -25 | 0.480        |
| -2  | 3.885        | 3.958          | -12 | 1.644        | 1.843          | -30 | 0.288        |
| -3  | 3.575        | 3.678          | -13 | 1.503        | 1.701          | -35 | 0.168        |
| -4  | 3.288        | 3.415          | -14 | 1.373        | 1.568          | -40 | 0.096        |
| -5  | 3.022        | 3.171          | -15 | 1.253        | 1.445          | -45 | 0.053        |
| -6  | 2.776        | 2.942          | -16 | 1.143        | 1.331          | -50 | 0.030        |
| -7  | 2.548        | 2.727          | -17 | 1.041        |                | -55 | 0.016        |
| -8  | 2.337        | 2.525          | -18 | 0.948        |                | -60 | 0.007        |
| -9  | 2.143        | 2.337          | -19 | 0.863        |                | -65 | 0.002        |



# Saturation Vapour Pressure of Water.

In mm. of Mercury at 0°C and lat. 45°.

| °C. | .0     | .1     | .2     | .3     | .4     | .5     | .6     | .7     | .8     | .9     |
|-----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 0   | 4.579  | 4.613  | 4.647  | 4.681  | 4.715  | 4.750  | 4.785  | 4.820  | 4.855  | 4.890  |
| 1   | 4.926  | 4.962  | 4.998  | 5.034  | 5.071  | 5.107  | 5.144  | 5.181  | 5.219  | 5.256  |
| 2   | 5.294  | 5.332  | 5.370  | 5.409  | 5.447  | 5.487  | 5.526  | 5.565  | 5.605  | 5.645  |
| 3   | 5.685  | 5.726  | 5.766  | 5.807  | 5.848  | 5.890  | 5.932  | 5.974  | 6.016  | 6.058  |
| 4   | 6.101  | 6.144  | 6.187  | 6.231  | 6.274  | 6.319  | 6.363  | 6.407  | 6.452  | 6.497  |
| 5   | 6.543  | 6.589  | 6.635  | 6.681  | 6.728  | 6.775  | 6.822  | 6.870  | 6.918  | 6.966  |
| 6   | 7.014  | 7.063  | 7.111  | 7.161  | 7.210  | 7.260  | 7.310  | 7.361  | 7.411  | 7.463  |
| 7   | 7.514  | 7.566  | 7.618  | 7.670  | 7.723  | 7.776  | 7.830  | 7.883  | 7.937  | 7.991  |
| 8   | 8.046  | 8.101  | 8.156  | 8.211  | 8.267  | 8.324  | 8.380  | 8.437  | 8.494  | 8.552  |
| 9   | 8.610  | 8.669  | 8.727  | 8.787  | 8.846  | 8.905  | 8.966  | 9.027  | 9.087  | 9.148  |
| 10  | 9.210  | 9.272  | 9.334  | 9.396  | 9.459  | 9.523  | 9.586  | 9.650  | 9.715  | 9.780  |
| 11  | 9.845  | 9.911  | 9.977  | 10.043 | 10.110 | 10.177 | 10.245 | 10.313 | 10.381 | 10.450 |
| 12  | 10.519 | 10.589 | 10.659 | 10.729 | 10.800 | 10.871 | 10.942 | 11.015 | 11.087 | 11.160 |
| 13  | 11.233 | 11.307 | 11.381 | 11.455 | 11.530 | 11.606 | 11.681 | 11.758 | 11.834 | 11.911 |
| 14  | 11.989 | 12.067 | 12.146 | 12.225 | 12.304 | 12.384 | 12.464 | 12.545 | 12.626 | 12.708 |
| 15  | 12.790 | 12.873 | 12.956 | 13.039 | 13.123 | 13.208 | 13.292 | 13.378 | 13.464 | 13.550 |
| 16  | 13.637 | 13.724 | 13.812 | 13.901 | 13.989 | 14.079 | 14.169 | 14.259 | 14.350 | 14.441 |
| 17  | 14.533 | 14.625 | 14.718 | 14.812 | 14.906 | 15.000 | 15.095 | 15.190 | 15.286 | 15.383 |
| 18  | 15.480 | 15.578 | 15.676 | 15.774 | 15.874 | 15.974 | 16.074 | 16.175 | 16.276 | 16.378 |
| 19  | 16.481 | 16.584 | 16.688 | 16.792 | 16.897 | 17.003 | 17.109 | 17.216 | 17.323 | 17.431 |
| 20  | 17.539 | 17.648 | 17.758 | 17.868 | 17.978 | 18.090 | 18.202 | 18.314 | 18.427 | 18.541 |
| 21  | 18.655 | 18.770 | 18.885 | 19.001 | 19.118 | 19.236 | 19.354 | 19.472 | 19.592 | 19.711 |
| 22  | 19.832 | 19.953 | 20.075 | 20.198 | 20.321 | 20.445 | 20.569 | 20.695 | 20.820 | 20.947 |
| 23  | 21.074 | 21.202 | 21.330 | 21.459 | 21.589 | 21.720 | 21.851 | 21.983 | 22.116 | 22.249 |
| 24  | 22.383 | 22.518 | 22.653 | 22.789 | 22.926 | 23.064 | 23.202 | 23.341 | 23.481 | 23.622 |
| 25  | 23.763 | 23.905 | 24.048 | 24.192 | 24.336 | 24.481 | 24.627 | 24.773 | 24.920 | 25.068 |
| 26  | 25.217 | 25.366 | 25.517 | 25.668 | 25.819 | 25.972 | 26.125 | 26.280 | 26.435 | 26.590 |
| 27  | 26.747 | 26.905 | 27.053 | 27.222 | 27.382 | 27.542 | 27.704 | 27.866 | 28.029 | 28.193 |
| 28  | 28.358 | 28.523 | 28.690 | 28.857 | 29.025 | 29.195 | 29.364 | 29.535 | 29.706 | 29.879 |
| 29  | 30.052 | 30.226 | 30.401 | 30.578 | 30.754 | 30.932 | 31.111 | 31.290 | 31.471 | 31.652 |
| 30  | 31.834 | 32.017 | 32.201 | 32.386 | 32.572 | 32.759 | 32.946 | 33.134 | 33.324 | 33.514 |
| 31  | 33.706 | 33.898 | 34.092 | 34.286 | 34.482 | 34.678 | 34.875 | 35.073 | 35.273 | 35.473 |
| 32  | 35.674 | 35.876 | 36.079 | 36.284 | 36.489 | 36.695 | 36.902 | 37.110 | 37.320 | 37.530 |
| 33  | 37.741 | 37.953 | 38.167 | 38.381 | 38.597 | 38.813 | 39.030 | 39.249 | 39.469 | 39.689 |
| 34  | 39.911 | 40.134 | 40.358 | 40.583 | 40.809 | 41.036 | 41.264 | 41.493 | 41.724 | 41.955 |
| 35  | 42.188 | 42.422 | 42.657 | 42.893 | 43.130 | 43.368 | 43.608 | 43.848 | 44.090 | 44.333 |



| °C. | 0      | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      |
|-----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 30  | 55.34  | 58.36  | 61.52  | 64.82  | 68.28  | 71.90  | 44.58  | 47.08  | 49.71  | 52.46  |
| 40  | 92.54  | 97.21  | 102.10 | 107.20 | 112.51 | 118.06 | 75.67  | 79.62  | 83.74  | 88.05  |
| 50  | 149.38 | 156.43 | 163.77 | 171.39 | 179.31 | 187.54 | 123.82 | 129.84 | 136.09 | 142.61 |
| 60  | 233.7  | 244.0  | 254.6  | 265.7  | 277.2  | 289.0  | 196.09 | 204.96 | 214.18 | 223.74 |
| 70  | 355.1  | 369.7  | 384.9  | 400.5  | 416.7  | 433.5  | 301.4  | 314.1  | 327.3  | 341.0  |
| 80  | 525.8  | 546.1  | 567.1  | 588.7  | 611.0  | 634.0  | 450.8  | 468.6  | 487.1  | 506.1  |
| 90  | 760.0  | 787.5  | 815.9  | 845.1  | 875.1  | 906.1  | 657.7  | 682.1  | 707.3  | 733.3  |
| 100 | 1074.5 | 1111.1 | 1148.7 | 1187.4 | 1227.1 | 1267.9 | 937.9  | 970.6  | 1004.3 | 1038.8 |
| 110 |        |        |        |        |        |        | 1309.8 | 1352.8 | 1397.0 | 1442.4 |

| °C. | Atmos. | °C. | Atmos. | °C.  | Atmos.    |
|-----|--------|-----|--------|------|-----------|
| 105 | 1.192  | 170 | 7.81   | 270  | 54.19     |
| 110 | 1.414  | 175 | 8.80   | 280  | 63.17     |
| 115 | 1.563  | 180 | 9.88   | 290  | 73.27     |
| 120 | 1.959  | 185 | 11.07  | 300  | 84.60     |
| 125 | 2.290  | 190 | 12.37  | 310  | 97.2      |
| 130 | 2.665  | 195 | 13.79  | 320  | 111.2     |
| 135 | 3.088  | 200 | 15.33  | 330  | 126.7     |
| 140 | 3.565  | 210 | 18.80  | 340  | 143.8     |
| 145 | 4.099  | 220 | 22.86  | 350  | 162.7     |
| 150 | 4.695  | 230 | 27.57  | 360  | 183.5     |
| 155 | 5.358  | 240 | 32.98  | 370  | 206.5     |
| 160 | 6.095  | 250 | 39.17  | 374* | 218       |
| 165 | 6.910  | 260 | 46.22  |      | *Critical |

The values from 0°C. to 50°C. are those given by Scheel and Heuse, *Ann. d. Phys.*, 1910, **31**, 715: the figures for each 0.1°C. from 0° to 35°C. have been interpolated from their results. From 51°C. to 80°C. the values are those calculated from Thiesen's formula (mean of all earlier deter-

minations), which requires 92.52 mm. at 50°C. instead of 92.54. From 80°C. to 200°C. Holborn and Henning's observations are tabulated, *Ann. d. Phys.*, 1908, **26**, 833, and above 200°C. those of Holborn and Baumann, *Ann. d. Phys.*, 1910, **31**, 968. 1 atmo. = 1.03326 kgs./cm<sup>2</sup> = 14.6974 lbs./in.<sup>2</sup>

## Vapour Pressures of Various Substances.

Interpolation. To find the vapour pressure at a temperature between any two given in the tables, interpolate logarithms of vapour pressures instead of the pressures themselves, since  $\log. p$  is approximately a linear function of  $t$  over short ranges.

More accurately, plot  $\frac{\theta_x}{\theta_w}$  against  $\theta_x$  where  $\theta_w$  is the absolute temperature at which the vapour pressure of water is equal to that of the substance at  $\theta_x$  absolute, using as many values of  $\theta_x$  as are given. Draw a straight line through these points and read off the value of  $\frac{\theta_x}{\theta_w}$  for the required temperature  $\theta'_x$ : the temperature  $\theta'_w$  given by this value of the ratio corresponds with a certain pressure  $p$  given in the tables for water: this pressure is also that exerted by the given substance at  $\theta'_x$ . If the points lie well on the straight line extrapolation is permissible except near the critical temperature and pressure.

Similarly to find the temperature at which the given substance shall exert a pressure  $p_1$ , plot  $\frac{\theta_x}{\theta_w}$  against  $\theta_w$  and find the value of the ratio for the temperature  $\theta''_w$  at which water has the pressure  $p_1$ . The temperature  $\theta''_x$  given by the value of  $\frac{\theta_x}{\theta_w}$  so found is that at which the substance also exerts the vapour pressure  $p_1$ .

|                          |   |             |        |                   |   |       |        |        |       |
|--------------------------|---|-------------|--------|-------------------|---|-------|--------|--------|-------|
| Hydrogen                 | $\theta$  | 14.20       | 16.94  | 19.03             | $p = \text{mm. of mercury. } P = \text{atmospheres.}$ | 20.39 | 20.62  | 27.29  | 32.93 |
| Cath and Onnes 1918      | $p$   | 61.8        | 232.5  | 602.3             |   | 760.0 | 810.9  | 3763   | 9364  |
| Oxygen                   | $\theta$  | 76.98       | 82.01  | 86.24             |   | 90.10 |        |        |       |
| Siemens 1913             | $p$   | 150         | 300    | 500               |   | 760   |        |        |       |
|                          | $\log. p = -\frac{399}{\theta} + 1.75 \log. \theta$   |             |        | $\theta - .01292$ | $\theta + 5.0527$                                     |       |        |        |       |
| Nitrogen                 | $\theta$  | 64.55       | 66.93  | 70.22             |   | 73.10 | 76.55  | 77.25  |       |
| Siemens 1913             | $p$   | 120         | 180    | 300               |   | 450   | 700    | 760    |       |
|                          | $\log. p = -\frac{345.6}{\theta} + 1.75 \log. \theta$   |             |        | $\theta - .01250$ | $\theta + 4.7306$                                     |       |        |        |       |
| Acetylene                | $t$   | -35 (solid) | -70    | -50               |   | -23.8 | 0.0    | 15     | 36.9  |
| Villard 1895             | $P$   | 1.00        | 2.22   | 5.3               |   | 13.2  | 26.05  | 37.9   | 68.0  |
| Ammonia                  | $t$   | -80*        | -64.4* | -50†              |   | -40†  | -33.5† | -20†   | -10†  |
| Brill.* Davies† 1906     | $p$   | 35.2        | 116    | 293               |   | 557   | 760    | 1393   | 2146  |
| Keyes 1918               | $t$   | 0           | 10     | 20                |   | 30    | 40     | 100    | 132.9 |
|                          | $P$   | 4.28        | 6.13   | 8.53              |   | 11.60 | 15.44  | 61.75  | 112.3 |
|                          | $\log. p = \frac{1969.65}{\theta} + 16.19785 - .0423858 \theta + 5.4131 \times 10^{-5} \theta^2 - 3.2715 \times 10^{-8} \theta^3$ |             |        |                   |   |       |        |        |       |
| Carbon dioxide           | $t$   | -114.5      | -106.8 | -97.2             |   | -89.2 | -79.5  | -78.44 |       |
| Siemens 1913             | $p$   | 20          | 50     | 170               |   | 300   | 700    | 760    |       |
|                          | $\log. p = -\frac{1378.3}{\theta} + 1.75 \log. \theta - .0051 \theta + 6.9484$  |             |        |                   |   |       |        |        |       |
| Kuenen and Amagat        | $t$   | -50         | -30    | -10               |   | 0.0   | +10    | 20     | 30    |
| Chlorine                 | $P$   | 6.60        | 14.0   | 26.0              |   | 34.35 | 44.4   | 56.4   | 70.7  |
| Pellaton 1915            | $t$   | -70         | -34.5  | 0                 |   | 20    | 40     | 60     | 144   |
| Hydrochloric acid        | $P$   | .147        | 1.00   | 3.64              |   | 6.57  | 11.14  | 17.5   | 76.10 |
| Cardoso 1913             | $t$   | -24.4       | -10    | 0.0               |   | +10   | 20     | 30     | 51.4  |
| Nitrous oxide            | $P$   | 12.62       | 19.29  | 25.42             |   | 32.99 | 41.65  | 52.10  | 81.55 |
| Calliottet, Villard 1897 | $t$   | -92         | -60    | -34               |   | 0.0   | 12     | 20     |       |
| Sulphur dioxide          | $P$   | 1.00        | 5.05   | 13.2              |   | 30.8  | 41.2   | 49.4   |       |
| Pictet                   | $t$   | -30         | -20    | -10               |   | 0.0   | +10    | 20     | 30    |
| Sulphuretted hydrogen    | $P$   | 0.36        | 0.61   | 1.00              |   | 1.51  | 2.35   | 3.30   | 4.60  |
| Regnault                 | $t$   | -20         | -10    | 0.0               |   | +10   | 20     | 30     | 40    |
|                          | $P$   | 5.8         | 8.0    | 10.8              |   | 14.3  | 18.6   | 23.7   | 29.7  |

# Vapour Pressures of Various Liquids and Solids.

|                            | $t = ^\circ\text{C.}, p = \text{mm. of mercury at } 0^\circ\text{C.}$ |     |       |       |       |       |
|----------------------------|---|-----|-------|-------|-------|-------|
|                            | $t$   | $p$ | $t$   | $p$   | $t$   | $p$   |
| Acetic acid                | 0   |     | 20    | 40    | 80    | 100   |
| Ramsay and Young           | 3.4   |     | 11.8  | 34.5  | 88.6  | 202.3 |
| Acetone                    | 20  |     | 30    | 40    | 50    | 60    |
| Regnault, Price 1918       | 183.0   |     | 282.3 | 420.8 | 615.3 | 760   |
| iso-Amyl alcohol           | 20  |     | 40    | 60    | 80    | 100   |
| Schmidt 1891               | 2.3   |     | 9.3   | 33.3  | 95.2  | 238.6 |
| Aniline                    | 43.1  |     | 87.2  | 119.4 | 138.7 | 161.1 |
| Kahlbaum 1898              | 1   |     | 25    | 100   | 200   | 400   |
| Benzene                    | -10   |     | +10   | 30    | 50    | 70    |
| Young 1889                 | 14.8  |     | 45.3  | 118.0 | 268.6 | 547.8 |
| Bromine                    | -16.6   |     | -5    | +8.2  | 23.4  | 40.5  |
| Ramsay and Young 1886      | 20  |     | 50    | 100   | 200   | 400   |
| Carbon disulphide          | -20   |     | -10   | 0     | 10    | 20    |
| Siemens 1913               | 46.5  |     | 78.4  | 127.0 | 198.1 | 298.3 |
| Chloroform                 | 20  |     | 30    | 40    | 50    | 60    |
| Regnault                   | 160.5   |     | 248   | 369   | 535   | 755   |
| Ether                      | -10   |     | 0     | 10    | 20    | 30    |
| Young 1910                 | 112.3   |     | 184.9 | 290.8 | 439.8 | 760   |
| Ethyl acetate              | 0   |     | 10    | 30    | 60    | 77.15 |
| Wade 1912                  | 24.1  |     | 42.9  | 118.7 | 415.1 | 760   |
| Ethyl alcohol              | -10   |     | 0     | 20    | 40    | 60    |
| Ramsay and Young 1886      | 6.5   |     | 12.7  | 44.0  | 133.4 | 350.2 |
| Iodine                     | 0   |     | 30    | 60    | 90    | 120   |
| Baxter 1915, Stelzner 1905 | .030  |     | .47   | 4.29  | 26.8  | 116.5 |
| Mercury                    | 20  |     | 50    | 100   | 200   | 300   |
| Laby 1908                  | .0011   |     | .0122 | .28   | 17.8  | 356.7 |
| Nitrobenzene               | 53.1  |     | 103.9 | 139.9 | 160.5 | 184.5 |
| Kahlbaum 1898              | 1   |     | 25    | 100   | 200   | 400   |
| Octane                     | 0   |     | 20    | 40    | 60    | 80    |
| Young 1900                 | 2.9   |     | 10.4  | 30.8  | 77.5  | 175   |
| Phenol                     | 44.8  |     | 90.2  | 120.2 | 139.0 | 160.0 |
| Kahlbaum 1898              | 1   |     | 25    | 100   | 200   | 400   |
| Phosphorus (yellow)        | 165   |     | 180   | 200   | 219   | 226   |
| Schrotter 1848             | 120   |     | 204   | 266   | 359   | 393   |
| Sulphur                    | 49.7  |     | 131.9 | 211.3 | 306.5 | 374   |
| Ruff 1908, Matthies 1906,  | .00034  |     | .081  | 3.14  | 53.5  | 240   |
| Rechenstein 1900           |   |     |       |       |       | 580   |

118.5  
760

136.85

760

183.9

760

90

1016

58.7

760

46.25

760

1042

100

1536.0

78.3

760

184.4

760

400

1566

208.3

760

125.7

760

181.4

760

287.3

760

444.6

760

# Total Vapour Pressure of Sulphuric Acid Water Mixtures .

In mm. of Mercury at °C.

(Burt, *J.C.S.*, 1904, 1339.)

| gms. $\text{H}_2\text{SO}_4$ in 100 gms. mixture. |        |          |          |        |          |          |        |        |        |
|---|--------|----------|----------|--------|----------|----------|--------|--------|--------|
| °C.   | 24.92. | 30.46.   | 35.54.   | 41.01. | 48.37.   | 54.24.   | 62.81. | 70.78. | 74.36. |
| 60  | 120.7  | 111.0    | 100.1    | 84.2   | 59.8     | 44.1     |        |        |        |
| 70  | 192.7  | 176.6    | 159.5    | 136.5  | 100.4    | 74.0     | 35.4   |        |        |
| 80  | 295.1  | 271.3    | 245.0    | 211.8  | 157.8    | 118.1    | 58.0   |        |        |
| 90  | 439.1  | 403.4    | 366.0    | 317.2  | 241.2    | 182.9    | 92.3   | 35.5   |        |
| 100   | 640.8  | 589.9    | 537.7    | 465.8  | 355.6    | 267.4    | 140.0  | 57.0   |        |
| 110   |        | 762.7    | 757.2    | 670.2  | 515.4    | 391.9    | 210.8  | 89.0   |        |
| 120   |        | (107.1°) | (109.6°) |        | 754.0    | 561.8    | 308.0  | 140.4  | 80.8   |
| 130   |        |          |          |        | (120.8°) | 753.7    | 438.3  | 205.2  | 120.4  |
| 140   |        |          |          |        |          | (128.7°) | 612.8  | 291.2  | 178.4  |
| 150   |        |          |          |        |          |          |        | 426.9  | 260.7  |
| 160   |        |          |          |        |          |          |        | 589.0  |        |

| % H <sub>2</sub> SO <sub>4</sub> . |          |          |        |        | % H <sub>2</sub> SO <sub>4</sub> . |     |        |        |        |
|------------------------------------|----------|----------|--------|--------|------------------------------------|-----|--------|--------|--------|
| °C.                                | 77.26.   | 78.50.   | 81.15. | 85.14. | 86.61.                             | °C. | 88.4.  | 91.01. | 95.94. |
| 110                                | 35.1     |          |        |        |                                    | 160 | 38.0   |        |        |
| 120                                | 56.1     | 47.7     |        |        |                                    | 170 | 59.4   |        |        |
| 130                                | 85.5     | 71.8     |        |        |                                    | 180 | 87.3   | 45.5   |        |
| 140                                | 127.7    | 108.0    | 65.3   | 31.5   |                                    | 190 | 120.5  | 67.9   | (205°) |
| 150                                | 188.9    | 163.7    | 101.7  | 51.3   | 37.7                               | 200 | 171.5  | 98.1   | 34.1   |
| 160                                | 273.9    | 235.2    | 150.4  | 77.6   | 57.7                               | 210 | 205.3  | 138.2  | 40.8   |
| 170                                | 387.1    | 329.8    | 218.9  | 115.0  | 87.3                               | 220 | (205°) | 190.3  | 60.8   |
| 180                                | 525.7    | 445.8    |        | 164.2  | 126.6                              | 230 |        | 263.5  | 85.9   |
| 190                                | 748.3    | 597.2    |        | 227.9  | 150.4                              | 235 |        |        | 106.0  |
| 200                                | (189.9°) | 756.8    |        | 307.4  | (185°)                             |     |        |        |        |
| 210                                |          | (198.3°) |        | 424.6  |                                    |     |        |        |        |
|                                    |          |          |        | (225°) | 670.3                              |     |        |        |        |

Except at the highest concentrations and temperatures (say above 90% acid and 180°C.) the partial pressure of sulphuric acid is negligible, and the total pressures given represent the partial pressure of aqueous vapour. Partial pressures of water for lower temperatures than are recorded by Burt are given in Sorel's table below, and may also be obtained from the relative humidity table which follows it, which has been calculated from Regnault's data.

# Partial Pressure of Aqueous Vapour above Diluted Sulphuric Acid.

In mm. of Mercury.

SOREL, 1889.

| °C. | gms. $H_2SO_4$ in 100 gms. of mixture of acid and water. |       |       |       |       |      |      |      |      |     |
|-----|--|-------|-------|-------|-------|------|------|------|------|-----|
|     | 44   | 48    | 52    | 56    | 60    | 64   | 68   | 72   | 76   | 80  |
| 10  | 4.4  | 3.7   | 3.0   | 2.2   | 1.6   | 1.2  | 0.9  | 0.7  | 0.4  | 0.2 |
| 30  | 15.5   | 13.4  | 10.9  | 8.1   | 6.1   | 4.0  | 3.0  | 2.0  | 1.4  | 0.8 |
| 50  | 48.3   | 40.1  | 31.5  | 24.1  | 16.9  | 10.9 | 7.2  | 4.8  | 3.0  | 1.9 |
| 70  |  | 107.2 | 84.5  | 65.0  | 46.1  | 30.3 | 19.4 | 12.0 | 7.5  | 4.1 |
| 90  |  |       | 207.9 | 160.0 | 118.7 | 83.7 | 56.0 | 33.7 | 18.5 | 9.3 |

## Air of Constant Humidity.

Regnault's table shows that the equilibrium pressure of aqueous vapour above dilute sulphuric acid, expressed as % of the maximum pressure above pure water at the same temperature is as follows:—

| °C. | gms. $H_2SO_4$ in 100 gms. mixture. |       |       |       |       |       |       |       |       |  |
|-----|-------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|--|
|     | 84.48                               | 73.13 | 64.47 | 57.65 | 52.13 | 43.75 | 37.69 | 33.10 | 24.26 |  |
|     | mols. $H_2O$ per mol. $H_2SO_4$ .   |       |       |       |       |       |       |       |       |  |
|     | 1                                   | 2     | 3     | 4     | 5     | 7     | 9     | 11    | 17    |  |
| 10  | 1.25                                | 5.46  | 13.09 | 20.57 | 33.05 | 48.73 | 63.03 | 70.05 | 84.15 |  |
| 20  | 0.89                                | 4.90  | 12.89 | 21.44 | 33.30 | 48.84 | 62.28 | 70.82 | 83.27 |  |
| 30  | 0.71                                | 4.72  | 12.87 | 22.23 | 33.87 | 49.44 | 62.11 | 70.22 | 82.78 |  |

This table has been calculated for the purpose of testing hygrometers, drying substances to constant, but not "dry" weight, etc.

The relative humidity of the air in equilibrium with a saturated solution of common salt is  $80.15 \pm 0.05\%$  between  $10^\circ C.$  and  $30^\circ C.$

Above caustic potash solutions, the relative humidity is as follows (after Wüllner):—

| °C. | gms. KOH in 100 gms. water. |      |      |      |      |
|-----|-----------------------------|------|------|------|------|
|     | 10                          | 20   | 30   | 40   | 49   |
| 10  | 94.0                        | 87.4 | 79.8 | 71.0 | 61.3 |
| 20  | 94.2                        | 87.7 | 80.1 | 71.3 | 61.8 |
| 30  | 94.2                        | 88.0 | 80.5 | 71.9 | 62.5 |

## Correction of Thermometer Readings.

The scientific standard thermometric scale is the thermodynamic or absolute scale: that of the constant-volume hydrogen thermometer agrees with this to within  $0.01^{\circ}\text{C}$ . between  $-100^{\circ}\text{C}$ . and  $+300^{\circ}\text{C}$ . and is the International Standard in practical use since 1887.

Mercury thermometers with N.P.L. certificates have corrections to reduce their readings to the constant-volume H scale. Those with class A or "precision" test certificate are tested, unless the contrary is expressly stated, immersed up to the point being read and in a vertical position, no account being taken of zero change. Those with class B or "Kew" certificate are tested totally immersed, and with thermometer vertical. Readings are always taken with a rising mercury meniscus.

The following fixed points may be used to reproduce the hydrogen scale from  $-200^{\circ}\text{C}$  to  $1100^{\circ}\text{C}$ .

oxygen b.p.  $-182^{\circ}.9_5 + 0^{\circ}.01258 (p-760) - 0^{\circ}.0000079 (p-760)^2$   
 $\text{CO}_2$  b.p.  $-78^{\circ}.5 + 0^{\circ}.01595 (p-760) - 0.0000111 (p-760)^2$   
 mercury f.p.  $-38^{\circ}.88$  ice m.p.  $0^{\circ}$   
 $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$  transition point to  $\text{Na}_2\text{SO}_4$  anhydrous  $32^{\circ}.38_4$   
 water b.p.  $100^{\circ}.0$  at 760 mm. (see Broch's table below for pressure corrections).  
 naphthalene b.p.  $217^{\circ}.9_6 + 0^{\circ}.058 (p-760)$  tin f.p.  $231^{\circ}.8_4$   
 benzophenone b.p.  $305^{\circ}.9 + 0^{\circ}.063 (p-760)$   
 cadmium f.p.  $320^{\circ}.9$  zinc f.p.  $419^{\circ}.4$   
 sulphur b.p.  $444^{\circ}.5_4 + 0.0904 (p-760) - 0.000052 (p-760)^2$   
 antimony f.p.  $630^{\circ}$  common salt f.p.  $801^{\circ}$   
 silver f.p.  $961^{\circ}$  in reducing atmosphere gold f.p.  $1063^{\circ}$   
 copper f.p.  $1083^{\circ}$  in reducing atmosphere.

These fixed points are used both by the N.P.L. and by the Reichsanstalt. For the m.pt.s. of palladium and platinum the accepted values are  $1549^{\circ}$  and  $1755^{\circ}$  (Day and Sosman, 1911).

For fixing the hydrogen scale between  $0^{\circ}$  and  $100^{\circ}\text{C}$ . when standard thermometers are not available, Richards (1918) has suggested the following transition-points of carefully purified hydrated crystalline salts, in addition to sodium sulphate:—

$\text{Na}_2\text{CrO}_4 \cdot 10\text{H}_2\text{O} \rightarrow \text{Na}_2\text{CrO}_4 \cdot 6\text{H}_2\text{O} + \text{solution } 19^{\circ}.525\text{C}$   
 $\text{Na}_2\text{CrO}_4 \cdot 10\text{H}_2\text{O} \rightarrow \text{Na}_2\text{CrO}_4 \cdot 4\text{H}_2\text{O} + \text{solution } 19^{\circ}.987\text{C}$   
 $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O} \rightarrow \text{Na}_2\text{CO}_3 \cdot 7\text{H}_2\text{O} + \text{solution } 32^{\circ}.017\text{C}$   
 $\text{NaBr} \cdot 2\text{H}_2\text{O} \rightarrow \text{NaBr} + \text{solution } 50^{\circ}.674\text{C}$   
 $\text{MnCl}_2 \cdot 4\text{H}_2\text{O} \rightarrow \text{MnCl}_2 \cdot 2\text{H}_2\text{O} + \text{solution } 58^{\circ}.089\text{C}$   
 $\text{SrCl}_2 \cdot 6\text{H}_2\text{O} \rightarrow \text{SrCl}_2 \cdot 2\text{H}_2\text{O} + \text{solution } 61^{\circ}.341\text{C}$   
 $\text{SrBr}_2 \cdot 6\text{H}_2\text{O} \rightarrow \text{SrBr}_2 \cdot 2\text{H}_2\text{O} + \text{solution } 88^{\circ}.62\text{C}$

Also benzene m.p.  $5^{\circ}.483\text{C}$



For calibrating Beckmann freezing-point thermometers to be used for milk, etc., Schoorl suggests (1915)

$\text{KNO}_3$ -ice eutectic (12.2%  $\text{KNO}_3$ ) m.p.  $-2^\circ.86$  C.

$\text{Ba}(\text{NO}_3)_2$ -ice eutectic (4.5%  $\text{Ba}(\text{NO}_3)_2$ ) m.p.  $-0^\circ.71$  C.

Direct comparison with standard instruments is more accurate than calibration between a few fixed points, and is recommended by the N.P.L. in preference to the calibration method for mercury thermometers.

Mercury thermometers should be used, whenever possible, under the conditions specified for their corrections. They should not be exposed to high temperatures longer than necessary, since this produces permanent rise of zero, sometimes masked by distillation of the mercury to the top of the stem. For work of any accuracy above  $200^\circ$  C., gas-filled capillaries are necessary to minimise distillation. High-range thermometers should have a few graduations near the ice point, and be checked frequently by observations of zero. When used *in vacuo*, thermometers may read  $0^\circ.1$  C. or so too low.

If an emergent column is unavoidable, the following tab may be used to reduce the error due to this cause if the thermometer has been standardised with thread immersed.

### Correction of Thermometer Readings for Emergent-stem.

If  $t$  be the indicated temperature,  $t_a$  the temperature of the air indicated by a second thermometer whose bulb is 10 cms. to the side of the middle of the exposed thread and is shielded from the source of heat, and  $n$  the number of degree divisions of the thread not immersed in the hot liquid or vapour, the correction which must be added to  $t$  according to Kopp,  $\delta t = .000143 n (t - t_a)$ . A graph for calculating  $\delta t$  from this formula is given by Wheeler, *J.S.C.* 1916, 35, 1198.

The following table gives values of  $\delta t$  in  $^\circ$  C. found experimentally by Rimbach, 1890, for Jena glass thermometers with solid stems, with degree divisions 1 to 1.6 mm. apart. The correction for German sleeve-thermometers may be up to  $0^\circ.25$  C. less for  $n=140$ . Sleeve-thermometers are not, however, as reliable for high temperatures as solid-stem thermometers.

The most accurate method of making the correction is, however, that suggested by Guillaume, in which the mean temperature of the emergent column is indicated by a



mercury in a piece of thermometer tubing with no bulb (preferably of the same bore and same glass), which is placed alongside the thermometer with its meniscus level with that being read, and its closed lower end reaching into the hot fluid. The graduations of the "stem thermometer" are of course very close together. The difference between the temperatures registered by the two thermometers multiplied by  $l/L-l$  is the required correction:  $L$  and  $l$  are the lengths of a degree on the main and "stem" thermometers respectively.

| $n$ | $t-t_a$ in °C. |      |      |      |      |      |      |      |      |
|-----|----------------|------|------|------|------|------|------|------|------|
|     | 70             | 80   | 90   | 100  | 120  | 140  | 160  | 180  | 200  |
| 10  | 0.02           | 0.03 | 0.05 | 0.07 | 0.11 | 0.17 | 0.21 | 0.27 | 0.33 |
| 20  | 0.13           | 0.15 | 0.18 | 0.22 | 0.29 | 0.38 | 0.46 | 0.53 | 0.61 |
| 30  | 0.24           | 0.28 | 0.33 | 0.39 | 0.48 | 0.59 | 0.70 | 0.78 | 0.88 |
| 40  | 0.35           | 0.41 | 0.48 | 0.56 | 0.68 | 0.82 | 0.94 | 1.04 | 1.16 |
| 50  | 0.47           | 0.53 | 0.62 | 0.72 | 0.88 | 1.03 | 1.17 | 1.31 | 1.44 |
| 60  | 0.57           | 0.66 | 0.77 | 0.89 | 1.09 | 1.25 | 1.42 | 1.58 | 1.74 |
| 70  | 0.69           | 0.79 | 0.92 | 1.06 | 1.30 | 1.47 | 1.67 | 1.86 | 2.04 |
| 80  | 0.80           | 0.91 | 1.05 | 1.21 | 1.52 | 1.71 | 1.94 | 2.15 | 2.33 |
| 90  | 0.91           | 1.04 | 1.19 | 1.38 | 1.73 | 1.96 | 2.20 | 2.42 | 2.64 |
| 100 | 1.02           | 1.18 | 1.35 | 1.56 | 1.97 | 2.18 | 2.45 | 2.70 | 2.94 |
| 110 |                |      |      | 1.78 | 2.19 | 2.43 | 2.70 | 2.98 | 3.26 |
| 120 |                |      |      | 1.98 | 2.43 | 2.69 | 2.95 | 3.26 | 3.58 |
| 130 |                |      |      |      | 2.68 | 2.94 | 3.20 | 3.56 | 3.89 |
| 140 |                |      |      |      | 2.92 | 3.22 | 3.47 | 3.86 | 4.22 |

## Correction of Boiling Points for Pressure.

(Mostly after S. Young).

If a temperature  $t^\circ$  C. be observed as the boiling point of a liquid under the pressure of  $p$  mms. of mercury at  $0^\circ$  C. the correction  $\delta t$  to be added to the observed b.p. to reduce it to that under the normal pressure of 760 mms. of mercury is  $\delta t = c(760 - p)(273 + t)$ .

The average value of  $c$  is 0.000120: this is correct within  $1 \times 10^{-6}$  for bromine, stannic chloride, *n*-heptane, *n*-octane, benzene, toluene, ethyl benzene, naphthalene, ethylene dibromide, the mono-haloid-benzenes, and ethyl ether. More

accurate results are given in the cases below by the following constants :—

|                             | $c \times 10^6$ |                          | $c \times 10^6$ |
|-----------------------------|-----------------|--------------------------|-----------------|
| Nitrogen .....              | 145             | Anthracene .....         | 108             |
| Argon .....                 | 138             | <i>m</i> -xylene .....   | 115             |
| Chlorine .....              | 126             | Triphenyl methane .....  | 108             |
| Iodine .....                | 116             | Naphthalene .....        | 119             |
| Ammonia .....               | 110             | Methyl chloride .....    | 126             |
| Sulphur dioxide .....       | 113             | Bromonaphthalene .....   | 115             |
| Carbon disulphide .....     | 127             | Methyl alcohol .....     | 100             |
| „ tetrachloride .....       | 123             | Ethyl „ .....            | 94              |
| Phosphorus trichloride .... | 123             | Propyl „ .....           | 94              |
| Silicon tetrachloride ..... | 126             | Amyl „ .....             | 98              |
| Water * .....               | 99              | Phenol .....             | 107             |
| All esters .....            | 114             | Acetic acid .....        | 107             |
| Methane .....               | 135             | Phthalic anhydride ..... | 112             |
| <i>n</i> -pentane .....     | 125             | Acetone .....            | 115             |
| <i>n</i> -hexane .....      | 122             | Benzophenone .....       | 109             |
| <i>iso</i> -pentane .....   | 127             | Anthraquinone .....      | 113             |
| Di- <i>iso</i> -butyl ..... | 125             | Aniline .....            | 112             |
| Hexamethylene .....         | 124             | Quinoline .....          | 115             |

Structurally similar substances have the same value of  $c$ .

\* See table following

## Boiling Point of Water at different Pressures. (Broch).

| mm. | °C.   | mm. | °C.   | mm. | °C.   | mm. | °C.    |
|-----|-------|-----|-------|-----|-------|-----|--------|
| 700 | 97.72 | 720 | 98.50 | 740 | 99.26 | 760 | 100.00 |
| 1   | 76    | 1   | 54    | 1   | 30    | 1   | 04     |
| 2   | 80    | 2   | 58    | 2   | 33    | 2   | 07     |
| 3   | 84    | 3   | 61    | 3   | 37    | 3   | 11     |
| 4   | 88    | 4   | 65    | 4   | 41    | 4   | 15     |
| 5   | 92    | 5   | 69    | 5   | 44    | 5   | 18     |
| 6   | 96    | 6   | 73    | 6   | 48    | 6   | 22     |
| 7   | 98.00 | 7   | 77    | 7   | 52    | 7   | 26     |
| 8   | 03    | 8   | 80    | 8   | 56    | 8   | 29     |
| 9   | 07    | 9   | 84    | 9   | 59    | 9   | 33     |
| 710 | 11    | 730 | 88    | 750 | 63    | 770 | 36     |
| 1   | 15    | 1   | 92    | 1   | 67    | 1   | 40     |
| 2   | 19    | 2   | 96    | 2   | 71    | 2   | 44     |
| 3   | 23    | 3   | 99    | 3   | 74    | 3   | 47     |
| 4   | 27    | 4   | 99.03 | 4   | 78    | 4   | 51     |
| 5   | 31    | 5   | 07    | 5   | 82    | 5   | 55     |
| 6   | 34    | 6   | 11    | 6   | 85    | 6   | 58     |
| 7   | 38    | 7   | 14    | 7   | 89    | 7   | 62     |
| 8   | 42    | 8   | 18    | 8   | 93    | 8   | 65     |
| 9   | 46    | 9   | 22    | 9   | 96    | 9   | 69     |

# Constant-Boiling Mixtures.

(Mostly after S. Young).

## I. Mixtures of Minimum Boiling Point

### (i) Binary mixtures.

| A.             | Mixture.                   | B.    | Boiling points °C. |        |          | % by wt. of A in mixture. |
|----------------|----------------------------|-------|--------------------|--------|----------|---------------------------|
|                |                            |       | A.                 | B.     | Mixture. |                           |
| Water          | Ethyl alcohol              | ..... | 100.0              | 78.39  | 78.13    | 4.41                      |
|                | <i>n</i> -propyl alcohol   | ..    | 100.0              | 97.2   | 87.7     | 28.31                     |
|                | <i>iso</i> -propyl alcohol | ..    | 100.0              | 82.45  | 80.35    | 12.10                     |
|                | <i>n</i> -butyl alcohol    | ....  | 100.0              | 117.5  | 92.25    | 37                        |
|                | <i>tert</i> -butyl alcohol | ..    | 100.0              | 82.55  | 79.9     | 11.76                     |
|                | Allyl alcohol              | ..... | 100.0              | 97.08  | 88.0     | 28                        |
|                | Butyric acid               | ..... | 100.0              | 159.5  | 99.2     | 80                        |
|                | Pyridine                   | ..... | 100.0              | 115    | 92.5     | 41                        |
|                | Methyl ethyl ketone        | ..... | 100.0              | 79.57  | 73.57    | 11.4                      |
|                | Ethyl acetate              | ..... | 100.0              | 77.15  | 70.37    | 8.43                      |
| Benzene        | Methyl alcohol             | ....  | 80.2               | 64.7   | 58.35    | 60.45                     |
|                | Ethyl alcohol              | ..... | 80.2               | 78.3   | 68.25    | 67.64                     |
|                | <i>n</i> -propyl alcohol   | ..    | 80.2               | 97.2   | 77.1     | 83.1                      |
|                | <i>iso</i> -propyl alcohol | ..    | 80.2               | 82.45  | 71.9     | 66.7                      |
|                | <i>iso</i> -butyl alcohol  | ..    | 80.2               | 108.05 | 79.85    | 90.7                      |
|                | <i>tert</i> -butyl alcohol | ..    | 80.2               | 82.55  | 73.95    | 63.4                      |
|                | Allyl alcohol              | ..... | 80.14              | 97.06  | 76.75    | 82.6                      |
|                | <i>n</i> -hexane           | ..... | 80.2               | 68.95  | —        | —                         |
|                | Carbon tetrachloride       | ..... | 80.2               | 76.75  | —        | —                         |
| Toluene        | Ethyl alcohol              | ..... | 110.6              | 78.3   | 76.7     | —                         |
|                | <i>n</i> -propyl alcohol   | ..    | 109                | 95.7   | 91.5     | 47                        |
|                | <i>iso</i> -butyl alcohol  | ..    | 109                | 105.8  | 100      | 57                        |
|                | Allyl alcohol              | ..... | 109                | 95.5   | 91.5     | 50                        |
| Methyl alcohol | <i>n</i> -hexane           | ..... | 64.7               | 68.95  | 50.0     | —                         |
|                | Chloroform                 | ..... | 64.7               | 60.5   | 54.0     | 12                        |
|                | Carbon tetrachloride       | ..... | 64.7               | 76.75  | 55.7     | 20.6                      |
|                | Ethyl bromide              | ....  | 64.7               | 38.0   | 35.5     | 5                         |
|                | „ iodide                   | ..... | 64.7               | 72.9   | 55       | 17                        |
|                | Methyl acetate             | ....  | 64.7               | 56.0   | 54.0     | 18                        |
|                | „ cyanide                  | ....  | 64.8               | 81.6   | 63.7     | 77                        |
|                | <i>iso</i> -butyl iodide   | ....  | 64.7               | 118.5  | 64.0     | —                         |
|                | Acetone                    | ..... | 65.5               | 56.6   | 55.95    | 13.5                      |
| Ethyl alcohol  | <i>n</i> -hexane           | ..... | 78.3               | 68.95  | 58.65    | 21                        |
|                | Chloroform                 | ..... | 78.3               | 61.15  | 59.4     | 7                         |
|                | Carbon tetrachloride       | ..... | 78.3               | 76.8   | 65.2     | 16.0                      |
|                | Ethyl bromide              | ....  | 77.8               | 38.0   | 37.0     | —                         |
|                | „ iodide                   | ..... | 77.8               | 72.0   | 63.0     | 14                        |
|                | <i>iso</i> -butyl iodide   | ....  | 77.8               | 118.5  | 77.0     | 70                        |

(i) *Binary mixtures—continued.*

| A.                         | Mixture.                      | B | Boiling points °C. |       |          | % by wt. of A in mixture. |
|----------------------------|-------------------------------|---|--------------------|-------|----------|---------------------------|
|                            |                               |   | A.                 | B.    | Mixture. |                           |
| Ethyl alcohol ..           | Methyl cyanide ....           |   | 78.4               | 81.6  | 72.6     | 55                        |
|                            | Ethyl acetate .....           |   | 78.39              | 77.15 | 71.81    | 30.98                     |
|                            | Carbon disulphide..           |   | 77.8               | 45.7  | 42.0     | 9                         |
| <i>n</i> -propyl alcohol   | <i>n</i> -hexane .....        |   | 97.2               | 68.95 | 65.65    | —                         |
|                            | Ethyl iodide .....            |   | 95.7               | 72.4  | 70.0     | 7                         |
|                            | <i>iso</i> -butyl iodide .... |   | 95.7               | 118.5 | 93.0     | 45                        |
|                            | Amyl bromide ....             |   | 95.5               | 118.2 | 94.0     | 70.7                      |
| <i>iso</i> -propyl alcohol | „ iodide .....                |   | 95.7               | 146.5 | 95.6     | 93                        |
|                            | Ethyl iodide .....            |   | 81.5               | 72.0  | 66.0     | 66                        |
|                            | <i>iso</i> -butyl iodide .... |   | 81.5               | 118.5 | 81.5     | 70                        |
|                            | Ethyl acetate .....           |   | 81.5               | 76.0  | 74.5     | 26                        |
| <i>iso</i> -butyl alcohol  | Carbon disulphide..           |   | 81.5               | 45.7  | 44.0     | 9                         |
|                            | <i>n</i> -hexane .....        |   | 108.05             | 68.95 | 68.1     | —                         |
|                            | Ethylene dibromide            |   | 105.8              | 129.5 | 105.0    | 62                        |
|                            | <i>iso</i> -butyl iodide .... |   | 105.8              | 118.5 | 101.5    | —                         |
| Amyl alcohol ..            | Amyl bromide ....             |   | 105.0              | 118.1 | 103.4    | 63.6                      |
|                            | „ iodide .....                |   | 104.8              | 146.5 | 104.7    | 95                        |
|                            | <i>o</i> -xylene .....        |   | 128.5              | 140.5 | 127.5    | —                         |
|                            | <i>m</i> -xylene .....        |   | 128.5              | 136.5 | 125.5    | 52                        |
| Acetic acid .....          | <i>p</i> -xylene .....        |   | 128.5              | 137.2 | 125.5    | 52                        |
|                            | Ethylene dibromide            |   | 128.5              | 129.5 | 121.5    | 30                        |
|                            | <i>iso</i> -butyl iodide....  |   | 128.5              | 118.5 | 115.5    | —                         |
|                            | Amyl bromide ....             |   | 123.0              | 117.9 | 116.15   | 12.7                      |
| Butyric acid ..            | „ iodide ....                 |   | 128.9              | 146.5 | 127.3    | 52                        |
|                            | Benzene .....                 |   | 118.5              | 80.2  | 80.05    | 2                         |
|                            | Toluene .....                 |   | 117.5              | 109   | 104      | 30                        |
|                            | <i>m</i> -xylene .....        |   | 117.5              | 136.5 | 114      | 27                        |
| Acetone .....              | Brombenzene .....             |   | 159.5              | 152.5 | 147.5    | 19                        |
| Carbon disulphide          | Carbon disulphide..           |   | 56.4               | 46.2  | 39.25    | 34                        |
|                            | Methyl acetate ....           |   | 56.0               | 56.0  | 55.5     | —                         |
|                            | Ethyl iodide .....            |   | 56.0               | 72.0  | 55.5     | 60                        |
|                            | Diethylamine .....            |   | 56.1               | 55.5  | 51.35    | 61.8                      |
| Ethyl acetate ..           | Methylal .....                |   | 46.2               | 42.05 | 37.25    | —                         |
|                            | Methyl acetate ....           |   | 45.6               | 56.0  | 39.5     | 71                        |
|                            | Ethyl acetate .....           |   | 45.6               | 76.0  | 46.0     | 92                        |
|                            | Ethyl bromide ....            |   | 45.6               | 38.0  | 37.5     | 32                        |
|                            | Ethyl ether .....             |   | 46.2               | 34.6  | 34.5     | —                         |
| Ethyl acetate ..           | Ethyl iodide .....            |   | 75.0               | 72.0  | 70.0     | 22                        |
|                            | Carbon tetrachloride          |   | 77.15              | 76.75 | 74.8     | —                         |

(ii) *Ternary Mixtures.*

| Mixture.                   | Boiling points °C. |          | Composition    |
|----------------------------|--------------------|----------|----------------|
|                            | Components.        | Mixture. | %<br>by weight |
| Water .....                | 100.0              |          | 7.4            |
| Benzene .....              | 80.2               | 64.85    | 74.1           |
| Ethyl alcohol .....        | 78.3               |          | 18.5           |
| Water .....                | 100.0              |          | 7.5            |
| Iso-Propyl alcohol .....   | 82.45              | 66.5     | 18.7           |
| Benzene .....              | 80.2               |          | 73.8           |
| Water .....                | 100.0              |          | —              |
| Ethyl alcohol .....        | 78.3               | 56.6     | —              |
| n-Hexane .....             | 68.95              |          | —              |
| Water .....                | 100.0              |          | 9.0            |
| Ethyl alcohol .....        | 78.39              | 70.23    | 8.4            |
| Ethyl acetate .....        | 77.15              |          | 82.6           |
| Water .....                | 100.0              |          | 3.4            |
| Ethyl alcohol .....        | 78.3               | 61.8     | 10.3           |
| Carbon tetrachloride ..... | 76.8               |          | 86.3           |
| Water .....                | 100.0              |          | 8.1            |
| Tert-butyl alcohol .....   | 82.55              | 67.3     | 21.4           |
| Benzene .....              | 80.2               |          | 70.5           |
| Water .....                | 100.0              |          | 8.6            |
| n-Propyl alcohol .....     | 97.2               | 68.5     | 9.0            |
| Benzene .....              | 80.2               |          | 82.4           |
| Water .....                | 100.0              |          | —              |
| n-Propyl alcohol .....     | 97.2               | 59.95    | —              |
| n-Hexane .....             | 68.95              |          | —              |
| Water .....                | 100.0              |          | 8.58           |
| Allyl alcohol .....        | 97.06              | 68.21    | 9.16           |
| Benzene .....              | 80.14              |          | 82.26          |
| Acetone .....              | —                  |          | 67.8           |
| Methyl acetate .....       | —                  | 54.9     | 8.9            |
| Methyl alcohol .....       | —                  |          | 23.3           |

II. *Mixtures of Maximum Boiling Point.*

| A.           | Mixture. | B.                   | Boiling points °C. |       |          | % of A<br>by wt. in<br>mixture |
|--------------|----------|----------------------|--------------------|-------|----------|--------------------------------|
|              |          |                      | A.                 | B.    | Mixture. |                                |
| Water        | .....    | Nitric acid          | 100.0              | 86.0  | 121.7    | 31.82                          |
|              |          | Hydrochloric acid..  | 100.0              | -80   | 110      | 79.76                          |
|              |          | Hydrobromic acid..   | 100.0              | -73   | 126      | 52.5                           |
|              |          | Hydriodic acid ....  | 100.0              | -35   | 127      | 43                             |
|              |          | Hydrofluoric acid .. | 100.0              | 19.4  | 120      | 63                             |
|              |          | Formic acid          | 100.0              | 99.9  | 107.1    | 23                             |
|              |          | Perchloric acid .... | 100.0              | 110   | 203      | 28.4                           |
| Pyridine     | .....    | Formic acid          | 117.5              | 100.0 | 149      | —                              |
|              |          | Propionic acid ....  | 117.5              | 140   | 149      | —                              |
| Picoline     | .....    | Acetic acid          | 134                | 118   | 145      | —                              |
| Methyl ether | ..       | Hydrochloric acid..  | -21                | -80   | -2       | 61                             |
| Chloroform   | ....     | Acetone              | 61.2               | 56.4  | 64.7     | 80                             |
|              |          | Methyl acetate ....  | 60.5               | 56    | 64.5     | 78                             |

## Some High-boiling Aqueous Solutions.

(After Gerlach 1887).

Concentrations in gms. anhydrous salt per 100 gms. water. Saturated solutions are indicated by \*, the corresponding b.p. being in brackets. The figures appear to be only rough approximations: different observers give sometimes widely different figures.

| °C.   | 120  | 140         | 160      | 180              |
|---|------|-------------|----------|------------------|
| CaCl <sub>2</sub>                             | 69   | 137         | 222      | *303 (178°)      |
| Citric acid                                   | 478  | 1720        | ∞ (166°) | —                |
| K acetate                                     | 134  | 309         | 609      | 626 (161°)       |
| K <sub>2</sub> CO <sub>3</sub>                | 128  | 219 (133°)  | —        | —                |
| KOH   | 57   | 92          | 222      | 153              |
| MgCl <sub>2</sub>                             | 49   | 63 (130°)   | —        | —                |
| Na acetate                                    | 146  | —           | —        | —                |
| NaNO <sub>3</sub>                             | *222 | —           | —        | —                |
| NaOH  | 51   | 93          | 151      | 230              |
| Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> | 214  | *348 (126°) | —        | —                |
| NaK tartrate                                  | 390  | 1087        | 6666     | ∞ (165°)         |
| NH <sub>4</sub> NO <sub>3</sub>               | 248  | 682         | 1370     | 2400 (explosive) |
| Pb acetate                                    | 3226 | ∞ (133°)    | —        | —                |
| Tartaric acid                                 | 374  | 980         | 3774     | ∞ (170°)         |

Potassium sulphocyanide has been recommended as a constant-temperature bath between 100° and 200° C. or higher up to 140° or so the temperature may be kept roughly constant by means of a constant-level arrangement which fixes the volume and hence the concentration and boiling-point.

## CRYSTALLOGRAPHY.

E. H. RODD, D.Sc.

The great advances in the technique of crystallography which have been made during the past few years have not only resulted in the gain of a much clearer insight into the structure of crystalline matter, but have pushed the boundaries of the science far into the territory of what was formerly supposed to be amorphous matter. On the one hand, the discovery of "fluid crystals" by Lehmann showed that some of the principal features of a crystal can be retained by matter in the fluid condition, and on the other hand it has been shown, by means of X-ray photographs, that such an apparently formless material as soot possesses a minutely crystalline structure. For most practical purposes, however, the old conception of a crystal suffices. A crystal, as distinct from crystalline matter, may be defined as a homogeneous solid body bounded by plane surfaces, the geometrical and physical properties of the body being, in general, different in different directions.

*Symmetry.* The number and distribution of the plane bounding surfaces or faces of a crystal are found always to conform to some geometrical law, and are consistent with the presence in the structure of some symmetrical homogeneous arrangement of the structural units. The character of the symmetry of a crystal can be determined more or less completely by a study of the distribution of the faces, although frequently assistance must be sought for its complete determination in other physical properties (optical, electrical, thermal, mechanical, etc.), which vary in magnitude according to the different directions in a crystal in which they are measured. Crystals are classified according to their degree of symmetry.

*Elements of Symmetry.* These are best considered in relation to a homogeneous structure of supposed indefinite extent, e.g., a regular point system. A crystal is such a structure bounded by plane surfaces, the number and distribution of which depend directly upon the symmetry elements of the homogeneous structure.



There are three kinds of symmetry, axes, planes or a centre.

An *axis* of symmetry may be 2, 3, 4 or 6 fold, according to the number of times the structure repeats itself, *i.e.*, comes into a position indistinguishable from that from which it started, during a complete revolution of  $360^\circ$  about that axis. In addition to a simple axis of rotation, a second kind of axis, termed a screw axis, is possible, which combines a rotation and a simultaneous translation or progression along the direction of the axis.

*Planes* of symmetry are such that the structure on one side of the plane bears to that on the other side the same relation as that of an object to its mirror image.

The effect a *centre* of symmetry is that of a rotation through an angle of  $180^\circ$  combined with a reflection in a plane perpendicular to the axis of rotation. Points at opposite ends of a straight line passing through and bisected by a centre of symmetry are therefore similar.

### *Classes and Systems of Symmetry*

It has been proved mathematically that there are only 32 possible classes of crystal symmetry, each distinguished by the possession of a certain combination of symmetry elements, axes, planes or a centre. All known crystals belong to one or other of these classes, and representatives of most of the possible classes have been discovered among actual crystals; one class of the tetragonal system and two classes of the trigonal system have, however, not yet been identified. For convenience the 32 classes are grouped in seven different systems. In each system the class which possesses the highest symmetry is called the *holohedral* class; classes of lower symmetry are called *hemihedral* or *tetartohedral*, according to whether the degradation of symmetry leads to the suppression of one-half or three-quarters of the number of faces of the most general form of crystal face. A *hemimorphic* class is a special type of hemihedral class, in which one-half of the holohedral planes occur independently, grouped about one extremity of an axis of symmetry. A hemimorphic crystal cannot therefore possess a centre of symmetry.

*Crystallographic axes.* For descriptive purposes crystals are referred to a system of axes, generally three, except in the hexagonal system, where four are used. Whenever possible, geometrical axes of symmetry are chosen for these axes of reference, but in systems of low symmetry this becomes impossible, and the crystallographic axes are then chosen with reference to important planes developed on the crystal.



## Characteristics of the Seven Crystal Systems.

I. The Cubic, Isometric or Regular system. This system comprises five crystal classes: *holohedral*; *gyroidal hemihedral*; *pentagonal hemihedral*; *tetrahedral hemihedral*; *tetartohedral*. The holohedral class possesses the full symmetry of the cube, namely, three four-fold, four three-fold and six two-fold axes, with nine planes of symmetry. Fig. 1 represents a cubic crystal on which are developed cube and rhombic dodecahedron faces; the four-fold axes emerge perpendicularly from the centre of each cube face; the three-fold axes at points such as A,

at which three rhombic dodecahedron faces meet; and the two-fold axes emerge perpendicularly from the centre of each dodecahedron face.

In the hemihedral and tetartohedral classes, certain of these elements of symmetry disappear, but the four three-fold axes are always present.

The three four-fold axes are chosen as the crystallographic axes for the cubic system. In fig. 1 these are shown dotted. They are all equal in length, and all at right angles.

II. The *Tetragonal* system. The crystals belonging to this system are referred to three axes, all at right angles, two being equal in length, the third unequal. The unequal or principal axis is one of four-fold symmetry in each of the seven classes belonging to this system, and there are also, in the holohedral class, four two-fold axes at right angles to the principal axis, and five planes of symmetry, four of which intersect in the principal axis, the other being perpendicular to it. Fig. 2, shows a ditetragonal bipyramid; the planes and axes can be readily distinguished.

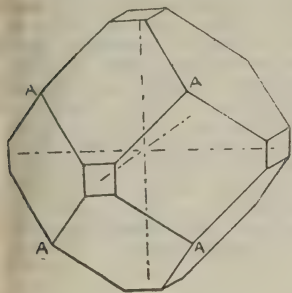


Fig. I.

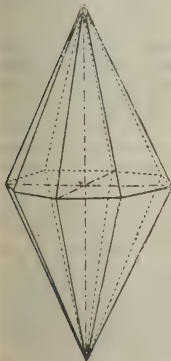


Fig. II.

III. The *Hexagonal* system. Crystals belonging to this system are referred to four axes. Three of these axes lie in a plane, making angles of  $60^\circ$  with one another; these are axes of two-fold symmetry in the holohedral class and are all equal. The fourth or principal axis is at right angles to the plane of the other three, and is unequal to them; its symmetry is six-fold. Fig. 3 represents a dihexagonal bipyramid. This system comprises five crystal classes.

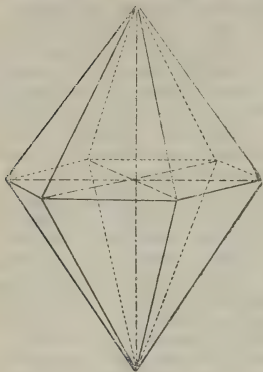


Fig. III.

IV. The *Rhombohedral* or *Trigonal* system. The seven crystal classes of this system are often grouped under the hexagonal system, being regarded as hemihedral hexagonal, the principal axis having been degraded from six-fold to three-fold symmetry. They are referred to the same system of axes as hexagonal crystals, or alternatively to a set of three oblique equal axes, the directions of which depend upon the angles of inclination of the faces of the fundamental rhombohedron. Fig. 4 shows a

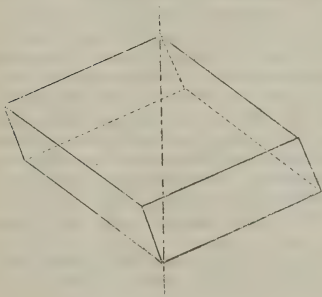


Fig. IV.

typical rhombohedron of calcspars, with the three-fold (trigonal) axis shown dotted.

V. The *Rhombic* or *Orthorhombic* system. Crystals belonging to this system are referred to three axes at right angles, all unequal in length. In the holohedral class, these axes are of two-fold symmetry, and there are also three planes of symmetry and a centre. Fig. 5 shows a typical rhombic crystal of sulphur with the axes dotted in. This system comprises three classes: holohedral, hemihedral and hemimorphic.

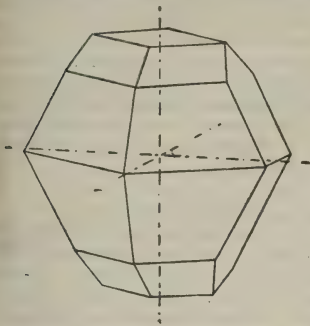


Fig. V.

VI. The *Monoclinic* or *Monosymmetric* system. Crystals belonging to this system possess only one axis of two-fold symmetry and one plane of symmetry perpendicular to this axis. The axis of symmetry is chosen as one crystallographic axis,  $b$ , the other two axes,  $a$  and  $c$ , being chosen arbitrarily in the symmetry plane. Hence, whilst  $b$  is at right angles to both  $a$  and  $c$ , these are inclined to one another at some angle  $\beta$ . Fig. 6 shows a crystal of ferrous sulphate in which the characteristic symmetry can be clearly seen,  $bb'$  being the axis of

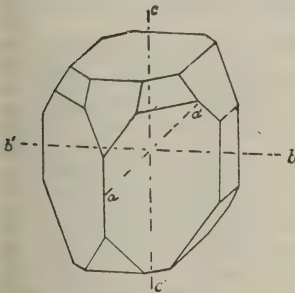


Fig. VI.

symmetry, the plane of symmetry being perpendicular thereto and containing the axes  $a$  and  $c$ . This system comprises three classes: holohedral; hemihedral, in which the axis of symmetry is lacking; and hemimorphic, in which the plane of symmetry is suppressed.

VII. The *Triclinic, Asymmetric* or *Anorthic* system. In this system there are neither planes nor axes of symmetry. The crystallographic axes are therefore chosen, in an arbitrary manner, with reference to certain faces developed on the crystal; they are all unequal and are not at right angles to one another. There are two classes of triclinic crystals; the holohedral class has a centre of symmetry, and each face on the crystal is accompanied by a corresponding parallel face; in the hemihedral class there is no centre, and any face may develop independently of any other.

*The Law of Rational Indices and Crystal Notation.*

The fundamental law which governs the development of faces on a crystal is the Law of Rational Indices. This empirical law states that the lengths of the intercepts of any face on the crystallographic axes must be simple multiples of the lengths of these axes. From this law has developed the current system of notation for crystal faces, now in such general use that other systems must be considered obsolete. Each face of a crystal is represented by indices which are reciprocals, reduced to their lowest terms, of the intercepts of the face on the three axes. If  $a, b, c$  are the axial lengths of a crystal and a face intercepts these axes at lengths, say,  $3a, 2b, 3c$ , the indices become  $(\frac{1}{3}, \frac{1}{2}, \frac{1}{3})$ , or, reduced to a common denominator, (232). A face which intercepts all three axes at unit length becomes (111).

In order to distinguish between different faces having the same indices, e.g., the eight faces (111), negative signs are introduced. In fig. 7 the opposite ends of the three axes intersecting at O are given opposite signs in the conventional manner. A face intercepting  $+a, +b, -c$  at unit length then becomes (11 $\bar{1}$ ), that intercepting  $-a, -b, -c$  is called ( $\bar{1}\bar{1}\bar{1}$ ), and so on.

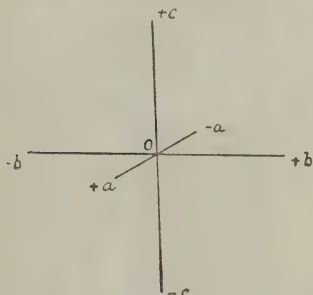


Fig. VII.

*Pinacoid* or *Basal Plane* faces, which intercept one axis and are parallel to the other two, receive indices (100), (010), (001).

*Dome or prism faces*, cutting two axes and parallel to the third, are of the type (110), (201), (032). For example, the rhombic dodecahedron of the cubic system is represented by twelve faces of the form (110), (011), (101), ( $\bar{1}10$ ), etc.

*Pyramid faces*, intersecting all three axes, are of the general form ( $h\ k\ l$ ); e.g., the octahedron of the cubic system is represented by eight faces (111), ( $\bar{1}11$ ), etc.

### *Crystal Form.*

If any one plane occurs as a crystal face, it must generally be accompanied by other faces in accordance with the symmetry of the class to which the crystal belongs. Thus if the face (111) develops on a holohedral cubic crystal, the other seven faces ( $\bar{1}11$ ), ( $1\bar{1}1$ ), etc., must also be present; if a cube face (100), develops, the other five cube faces ( $\bar{1}00$ ), (010), (001), etc., must appear. In the tetragonal system, however, (001) is accompanied only by ( $00\bar{1}$ ), not by (100) and (010), since the axis  $c$  is not equivalent to  $a$  and  $b$ . Such a complete group of faces is known as a *crystal form*.

### *Axial Ratios.*

In the cubic system the axes are all equal,  $a : b : c = 1 : 1 : 1$ . In the other systems, in which two or more axes are unequal, their relative lengths are calculated from the inclinations of faces to the axes by the usual trigonometrical formulæ. In the tetragonal system they become  $a : b : c = 1 : 1 : x$ , or  $a : c = 1 : x$ , since  $a$  and  $b$  are equivalent.

In the hexagonal and trigonal systems, also,  $a : c = 1 : x$ ,  $c$  being the principal axis.

In the orthorhombic system,  $a : b : c = x : 1 : y$ .

In the monoclinic system, in which the angle between the axes  $a$  and  $c$  is not a right angle, the interaxial angle must be stated, thus:  $a : b : c = x : 1 : y$ ;  $\beta = ?$

In the triclinic system, all three interaxial angles must be stated:  $a : b : c = x : 1 : y$ ;  $\alpha = ?$ ;  $\beta = ?$ ;  $\gamma = ?$

It is important to notice that in all systems except the cubic there is a certain amount of latitude in the choice of axial ratios for any particular crystal. Thus in the orthorhombic system, any pyramid face, i.e., any face which cuts all three axes, may be chosen as (111). This face then determines the axial ratios, and other faces receive indices to correspond, e.g., (121), (212). But if (121) were chosen as (111), the others become (212) and (414) respectively. The general considerations governing the choice of axial ratios usually lead to the simplest set of indices being assigned to the different faces on the crystal. The same applies to the choice of suitable axes in the monoclinic and triclinic systems.

### *Topic Axial Ratios or Topic Parameters.*

For the purpose of comparing the crystals of related substances, topic parameters are often used. By calculating three numbers  $\chi : \psi : \omega$  in the same ratio as the axial ratios, and the product of which is equal to the molecular volume,  $V$ , the dimensions of a parallelopipedal cell containing one molecular unit of the crystal are obtained. The formulæ for this calculation, in the general case of a triclinic crystal, are :

$$\chi = \sqrt[3]{\frac{a^2 V}{c \sin A \sin \beta \sin \gamma}}$$

$$\psi = \frac{\chi}{a}$$

$$\omega = c\psi$$

where  $\beta$  and  $\gamma$  are interaxial angles, and  $A$  is the angle between the pinacoid faces  $b(010)$  and  $c(001)$ . In those systems in which the axes are all at right angles,  $\sin A$ ,  $\sin \beta$  and  $\sin \gamma$  are all equal to 1.

*Optical properties.* Cubic crystals, on account of their high symmetry, are always singly refracting. All others exhibit double refraction.

The principal axis of symmetry in tetragonal, hexagonal and rhombohedral crystals is a unique optic axis. Orthorhombic, monoclinic and triclinic crystals show two optic axes.

Crystals which exist in enantiomorphous forms have the power of rotating the plane of polarisation of light. This property is in some cases due to the enantiomorphous arrangement of the molecules in the crystal, as in quartz; in others to the asymmetry of the molecule, as in *d*- and *l*-tartaric acid.

*Cleavage.* Many crystals exhibit the property of readily cleaving along certain directions, the cleaved surface being perfectly plane and bright. The cleavage plane is always a possible crystal face with simple indices, and is generally developed as a face on the crystal.

*Twinning.* Twin crystals are formed by the simultaneous development of two individuals from a common plane, termed the twinning plane. At other times the crystals show complete interpenetration, and are known as penetration twins. Again, repeated twinning may lead to the production of an apparent individual of higher symmetry than that which the real individual crystals possess. Twinning can generally be detected through the presence of re-entrant angles.



*Isomorphism.* Two substances having the same or practically the same crystalline form are said to be isomorphous. Isomorphous substances generally have very nearly equal axial ratios, belong to the same class of symmetry, and form mixed crystals or parallel growths. Isomorphism is generally only found among substances having similar chemical structure, *e.g.*, the sulphates and selenates of potassium, rubidium and caesium, or *p*-dichlor- and *p*-dibrombenzene.

*Dimorphism.* A substance which can crystallise in two distinct forms is said to be dimorphous; if in three forms, trimorphous, etc.

*Isodimorphism.* If two substances A and B crystallise in two separate systems, and at the same time form mixed crystals in either or both of these systems according to the proportion of A or B present in the mixture, they are said to be isodimorphous.

*Morphotropic relationships* are frequently observed between crystals of substances which are closely related chemically, but not so closely as to give rise to isomorphism. Such relationships usually take the form of similarity between one or both axial ratios; or a certain change of chemical composition may produce elongation or contraction in one direction only in the crystal structure.

### Construction of Crystal Axes.

In order to draw a crystal in the conventional manner, the crystallographic axes must first be constructed. This is done as follows: Two lines  $LL'$  and  $KK'$  are drawn at right angles, intersecting at  $O$ .  $KO$  is made  $= K'O$ , and  $KK'$  is trisected. Vertical lines are drawn through  $K'$  and  $K$  and the points of trisection, and below  $K'$   $K'H$  is made  $= \frac{1}{2} K'O$ . The line  $HO$  is produced, and the lateral axis  $a$  obtained, its length being  $AA'$ . Next  $AS$  is drawn parallel to  $KK'$ , and  $SO$  joined, cutting the inner vertical line at  $T$ .  $TB$  is drawn parallel to  $K'K$ , and from  $B$   $BB'$  is drawn through  $O$ . This line  $BB'$  is then the second lateral axis.

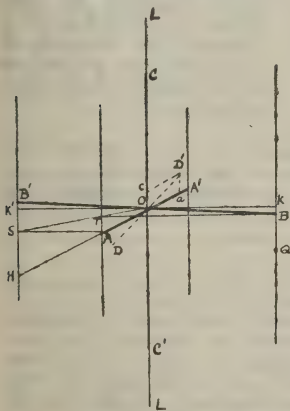


Fig. VIII

Below K KQ is made  $= \frac{1}{3} KO$ , and OC and OC' are made equal to OQ. The line CC' is then the third, vertical axis.

The three lines AA', BB', CC' represent the projection of three equal axes at right angles, the axes of the cubic system. They can be modified to give tetragonal or rhombic axes by changing the lengths of AA' or CC' according to the axial ratios, BB' being kept constant.

To obtain monoclinic axes, in which the angle between the axes  $a$  and  $c$  is  $\beta$ , Oc is made  $= OC \cos \beta$  and  $Oa = OA \sin \beta$ . From  $c$  and  $a$  lines are drawn parallel to OA' and OC, and from their point of intersection, D'D is drawn through O. This line gives the direction of the axis  $a$  inclined at an angle  $\beta$  to the axis  $c$ . The relative lengths of the axes are determined as for the orthorhombic system.

To draw the axes for a hexagonal crystal, of which the axial ratio  $a:c$  is given, orthorhombic axes are first constructed having the ratios  $\sqrt{3}:1:c$ . The extremities of AA', BB' are joined to form a rhomb (Fig. 9). The lines OA, OA' are then bisected, and through the points of bisection the lines  $a, a_1$  are drawn parallel to BB'. There is thus formed a hexagon, the diagonals of which are the projections of the three lateral hexagonal axes.

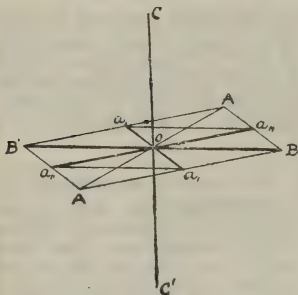


Fig. IX.

The construction of the crystal on the axes depends upon finding the lines of intersection of the various faces of the crystal, the intercepts of which upon the axes are known from their indices. This is done by the ordinary methods of solid geometry.

### *X-rays and Crystals.*

Important discoveries have recently been made in connection with X-rays and crystals. A crystal acts towards X-rays as a three-dimensional diffraction grating, by virtue of the homogeneous arrangement of the atoms in the structure in series of consecutive planes in different directions. By studying the reflection of pencil of monochromatic X-rays from crystal



faces, *i.e.*, from the important planes of atoms, an important relationship has been found between the angle of incidence which produces reflection, the wave-length of the X-rays, and the structure of the crystal. This law is expressed by the equation :

$$n \lambda = 2d \sin \theta,$$

where  $\theta$  is the angle of incidence,  $\lambda$  is the wave-length,  $n$  is the order of the reflected spectrum, and  $d$  is the perpendicular distance between successive planes of atoms which give the reflection. It is evident that, when X-rays of known wave-length are used, and  $\theta$  and  $n$  are determined experimentally,  $d$  can be calculated. In this way, great progress has been made with the intimate study of the internal structure of crystals. If  $d$  is determined in the three principal directions in the structure, the absolute dimensions of the unit parallelepipedal cell of the structure are found, and from the density of the crystal, and a knowledge of the mass of a hydrogen atom, the number of atoms or molecules in this crystal space unit can be determined. Researches along these lines with such crystals as rock salt, sylvine, diamond, pyrites and zinc blende have led to definite conclusions as to the disposition of the actual atoms in the crystals of each of these substances being drawn.

The reflection of X-rays by crystals has recently been applied by Hull in the development of a delicate method of chemical analysis (*J. Amer. Chem. Soc.*, 1919, **41**, 1168—1175). The specimen to be examined, of which only a minute quantity is required, is finely powdered and placed in a thin tube of glass or other truly amorphous material. A pencil of monochromatic X-rays is then caused to pass through the specimen, and the scattered rays impinge on a strip of sensitized photographic film. The film, when developed, shows a characteristic line spectrum, which is distinct for any pure chemical compound. From the character of spectrum given by the specimen, its purity can be gauged, and the nature of any impurity present can be told if its characteristic spectrum is known. This method, yet in its infancy, should be capable of further development.

---

## Properties

| Name.  | Composition.  | (1) Cryst System. | Specific Gravity.           | (2) Hardness   |
|--|---|-------------------|-----------------------------|----------------|
| 1 Acanthite  | $\text{Ag}_2\text{S}$   | I                 | 7.2—7.3                     | 2.5            |
| 2 Actinite (See Monoclinic Pyroxene. Essentially $\text{Na}_2\text{O}$ . |   |                   | $\text{Fe}_2\text{O}_3$ . 4 | $\text{SiO}_2$ |
| 3 Actinolite   | See Amphibole.  |                   |                             |                |
| 4 Adamine  | $\text{Zn}_3(\text{AsO}_3)_2 \cdot \text{H}_2\text{O}$  | IV.               | 4.3                         | 3.5            |
| 5 Adularia   | See Orthoclase.   |                   |                             |                |
| 6 Aeschynite   | $\text{Ce}_2(\text{Ca}, \text{Fe})_2 (\text{Ti}, \text{Th})_8 \text{O}_{21} \cdot 2\text{Ce}(\text{C}_2\text{O}_3)_4$ | IV.               | 4.9—5.1                     | 5—6            |
| 7 Agalmatolite   | $\text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot \text{H}_2\text{O}$  | I.                | 7.2—7.3                     | 2.5            |
| 8 Agaric Mineral   | See Calcite. White, earthy variety  |                   |                             |                |
| 9 Agate  | See Chalcedony and Silica.  |                   |                             |                |
| 10 Aikenite  | $\text{Bi}_2\text{S}_3$ with Pb and Cu  | III.              | 9.7—9.8                     | 2—2.5          |
| 11 Alabandin   | $\text{MnS}$  | tetr. h. I.       | 3.9—4.1                     | 3.5—4          |
| 12 Alabaster   | See Gypsum.   |                   |                             |                |
| 13 Albite  | $\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 + \text{Na}_2\text{O} \cdot 3\text{SiO}_2$                                 | VI.               | 2.59—2.65                   | 6—7            |
| 14 Allophane   | $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2 + 5\text{H}_2\text{O}$  | Am.               | 1.7—1.8                     | 3              |
| 15 Almandine   | $6\text{FeO} \cdot 3\text{SiO}_2 + 2\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2$  | I.                | 3.7—4.21                    | 6.5—7.3        |
| 16 Alstonite (Baryto Calcite)  | $\text{BaCO}_3 \cdot \text{CaCO}_3$   | V.                | 3.6                         | 4              |
| 17 Altaite   | $\text{PbTe}$   | I.                | 8.16                        | 3—3.5          |
| 18 Alum  | $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$                                   | I. pent. h.       | 1.75                        | 2—2.5          |
| 19 Aluminite   | $\text{Al}_2\text{SO}_6 + 9\text{H}_2\text{O}$  | Am.               | 1.66                        | 1—2            |
| 20 Alumstone   | $3 (\text{Al}_2\text{SO}_6) + \text{K}_2\text{SO}_4 + 6\text{H}_2\text{O}$  | III.              | 2.58—2.75                   | 3.5—4          |
| 21 Alumite   | See Alumstone.  | Rh. h.            |                             |                |

(1) *Crystallographic Systems*:—I. cubical (isometric); II. tetragonal; III. hexagonal; IV. rhombic; V. monoclinic; VI. triclinic. Am.=amorphous; h.=hemihedral; t.=tetartohedral; (h.)=hemimorphous; pyr.=pyramidal; rh.=rhombohedral; sph.=sphenoid; tetr.=tetrahedral; trap.=trapezohedral; pent.=pentagonal.

(2) *Moh's Mineralogical Scale of Hardness*:—(1) talc; (2) rock-salt (or gypsum); (3) calc-spar (transparent variety); (4) fluor-spar (cryst. var.); (5) apatite (transparent crys. var.); (6) orthoclase; (7) quartz (transparent var.); (8) topaz (cryst.); (9) sapphire (corundum); (10) diamond.

(3) *Lustre*:—Met.=metallic; vit.=vitreous; res.=resinous; py.=pearly; sy=silky; ad.=adamantine; wax.=waxy.

## of Minerals.

| (3)<br>Lustre.    | (4)<br>Colour.         | Streak. | (5)<br>Fracture.            | (6)<br>Fusibility. | (7)<br>Solubility.  |          |
|-------------------|------------------------|---------|-----------------------------|--------------------|---|----------|
| Met.              | B. Gr.                 | B.      | Uneven                      | E. fus.            | E.s. in $\text{HNO}_3$  | 1        |
| Vit.              | Gr.                    |         |                             |                    |   | 2        |
| Vit.              | Y., R., Gr.,<br>Violet | Y.W.    | $\infty p \infty$<br>cryst. |                    |   | 3        |
|                   | C. str.                |         |                             | $E_1$ fus.         | E.s. HCl  | 4        |
| Res.—sub.<br>met. | Bl.—Br., Y.            | Y. Br.  |                             | Inf.               | decomp.   | 5        |
| Dull              | Y. Gr. P. G.           | B.      | Uneven                      | E. fus.            | $\text{H}_2\text{SO}_4$<br>E.s. in $\text{HNO}_3$<br>with sepn. of S. | 6<br>7   |
|                   |                        |         |                             |                    |   | 8        |
| Met.              | W.—P.                  | W.—P.   | Cryst.                      | E. fus.            | s. in $\text{HNO}_3$  | 9        |
| Sub. met.         | Bl. Br.                | Bl. Gr. | $\infty O \infty$           | 5                  | s. in HCl   | 10       |
|                   | Pure W.                |         |                             |                    |   | 11       |
| Py. or vit.       | C. or W.               | C.      | Uneven<br>v. brittle        | D. fus.            | gelatinous $\text{SiO}_2$<br>with HCl                                 | 12<br>13 |
| Res. or wax.      | W.; P. Y.<br>Gr. or Br | C.      | Conch.                      | Inf.               | gelatinous $\text{SiO}_2$<br>with HCl                                 | 14       |
| Vit.              | Deep R.                | W.      | Sub-conch.<br>uneven        | 3                  | slight decomp.<br>by HCl  | 15       |
| Vit. or res.      | W. Gr. or Br.          | W.      | Uneven                      | D. fus.            | E.s. HCl  | 16       |
| Met.              | W. Y.                  | W.      | $\infty O \infty$           | Fus.               | E.s. $\text{HNO}_3$   | 17       |
| Vit.              | W.                     | C.      | Cryst.                      | E. fus.            | E.s. $\text{H}_2\text{O}$   | 18       |
| Earthy            | W.                     | W.      | Earthy<br>conch.            | Inf.               | s. HCl  | 19       |
| Vit. or dull      | W. Gr. or P            | W.      | Uneven<br>or earthy         | Inf.               | D.s. $\text{H}_2\text{SO}_4$  | 20       |
|                   |                        |         |                             |                    |   | 21       |

(4) *Colour*.—C. colourless; W. white; R. red; P. pink; B. blue; Y. yellow; G. green; Br. brown; Bl. black; Gr. grey.

*Diaphaneity*.—tr.=transparent; tl.=translucent; str.=subtransparent; stl.=subtranslucent; op.=opaque.

(5) *Fracture*.—Cryst.=crystalline fracture or cleavage; conch.=conchoidal.

(6) *Fusibility*.—(1) Antimony glance (antimonite); (2) natrolite (mesotype); (3) almandine garnet; (4) actinolite; (5) orthoclase; (6) Bronzite. Fus.=fusible;  $e_1$  fus.=easily fusible; d. fus.=difficultly fusible; inf.=infusible.

(7) *Solubility*.—s.=soluble; e.s.=easily soluble; d.s.=difficultly soluble. The name of the solvent is given after the degree of solubility, e.g., d. sol.  $\text{HNO}_3$ , =difficultly soluble in  $\text{HNO}_3$ .

|    | Name.  | Composition.   | Cryst. System.                | Specific Gravity. | Hardness. |
|----|--|--|-------------------------------|-------------------|-----------|
| 1  | Alum, Ammonia  | $(\text{NH}_4)_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3$<br>24 $\text{H}_2\text{O}$   | l. pent. h.                   | 1.63—1.75         | 1.5       |
| 2  | - Iron   | $\text{FeSO}_4 \cdot \text{Al}_2(\text{SO}_4)_3$<br>24 $\text{H}_2\text{O}$  | I                             | 1.712             | 1.7       |
| 3  | - Soda   | $\text{Na}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3$<br>24 $\text{H}_2\text{O}$   | l. pent. h.                   | 1.6—1.8           | 2.0—2.5   |
| 4  | - Magnesia   | $\text{MgSO}_4 \cdot \text{Al}_2(\text{SO}_4)_3$<br>18 $\text{H}_2\text{O}$  | I.                            | 1.53—1.8          | 1.5—2.0   |
| 5  | Alunogene  | $\text{Al}_2\text{O}_3 \cdot \text{SO}_3 + 18 \text{H}_2\text{O}$  | V                             | 1.6—1.8           | 1.5—2.0   |
| 6  | Amalgam  | Ag with Hg   | l. rh.                        | 10.5—14           | 3—3.5     |
| 7  | Amazonstone  | See Microcline.  |                               |                   |           |
| 8  | Amber  | Fossil resin, Bitumen class  | Am                            | 1.08              | 2—2.5     |
| 9  | Amblygonite  | $\text{Li}(\text{Al}, \text{F})\text{PO}_4$  | VI                            | 3—3.11            | 6         |
| 10 | Amblystegite   | See Enstatite. (Contains more iron than Hypersthene)   | ns more iron than Hypersthene | 3.90—4.16         | 9         |
| 11 | Amethyst (Oriental or true)  | $\text{Al}_2\text{O}_3$  | III.                          | 3.90—4.16         | 9         |
| 12 | Amethyst   | $\text{SiO}_2$ with Mn, or (Fe and Na)   | III. rh.                      | 2.5—2.8           | 7         |
| 13 | Amianthus  | See Asbestos (Silky variety)   |                               |                   |           |
| 14 | Amphibole  | $\text{Ca}(\text{Mg}, \text{Fe})_3(\text{SiO}_3)_4$ with $\text{Na}_2\text{Al}_2(\text{SiO}_3)_4$ and $(\text{Mg}, \text{Fe})_2(\text{Al}, \text{Fe})_4\text{Si}_2\text{O}_{11}$ | V                             | 2.9—3.4           | 5—6       |
| 15 | Amphigene  | See Leucite.   |                               |                   |           |
| 16 | Analcime   | $\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 + \text{Na}_2\text{O}$ ,<br>$\text{SiO}_2 + 2 \text{H}_2\text{O}$   | I. trap.                      | 2.22—2.29         | 5—5.5     |
| 17 | Anatase  | $\text{TiO}_2$   | II. pyr.                      | 3.75—3.9          | 5.5—6     |
| 18 | Andalusite   | $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2$   | IV                            | 3.1—3.3           | 7.5       |
| 19 | Andesine   | See Felspar. (Between Oligoclase and Labradorite)  | VI.                           | 2.6—2.7           | 5—6       |
| 20 | Andradite  | See Garnet, Iron-lime.   |                               |                   |           |
| 21 | Anglesite  | $\text{PbSO}_4$  | IV.                           | 6.12—6.39         | 2.75—3    |
| 22 | Anhydrite  | $\text{CaSO}_4$  | IV.                           | 2.8—2.97          | 3—3.5     |
| 23 | Ankerite   | $(\text{Ca}, \text{Fe}, \text{Mg}, \text{Mn}) \text{CO}_3$   | III. rh. h.                   | 2.9—3.2           | 3.5—4     |
| 24 | Annabergite  | $\text{Ni}_3\text{As}_2\text{O}_8 + 8\text{H}_2\text{O}$   | V.                            | 3—3.1             | 2—2.5     |
| 25 | Annerödite   | $(\text{U}, \text{Y}, \text{Th}, \text{Ce}, \&c.)$<br>$(\text{NbO}_3)_2$   | IV.                           | 5—6               | 5         |
| 26 | Anomite  | Contains lithium.  | See Biotite.                  |                   |           |
| 27 | Anorthite  | $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2 + \text{CaO} \cdot \text{SiO}_2$   | VI. prism                     | 2.66—2.78         | 6—7       |
| 28 | Anorthoclase   | $\text{Na}_2\text{O} \cdot 2\text{SiO}_2 + \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$  | VI.                           | 2.6               | 6         |
| 29 | Anthophyllite  | $(\text{Mg}, \text{Fe}) \text{O} \cdot \text{SiO}_2$   | IV.                           | 3.2               | 5.5       |
| 30 | Anthracite   | C (95 per cent.)   | Am.                           | 1—1.8             | 2—2.5     |
| 31 | Anthraconite   | $\text{CaCO}_3$ with bituminous matter   | Am.                           | 2.6—2.7           | 2.5       |
| 32 | Antimony   | Sb   | III. rh.                      | 6.6—6.7           | 3—3.5     |
|    | Antimony Blende, (antimonite, stibnite, antimony glance, grey antimony). | $\text{Sb}_2\text{S}_3$  | IV.                           | 4.5—4.6           | 2         |

| Lustre.                  | Colour.                                 | Streak.  | Fracture.                | Fusibility. | Solubility.                                   |    |
|--------------------------|---|----------|--------------------------|-------------|---|----|
| Vit.                     | W.                                      | W.       | Am.                      | E. fus.     | E.s. H <sub>2</sub> O                         | 1  |
| Vit.                     | Violet                                  | W.       | Am.                      | E. fus.     | E.s. H <sub>2</sub> O                         | 2  |
| Soapy                    | C.W.                                    |          | Am.                      | E. fus.     | E.s. H <sub>2</sub> O                         | 3  |
|                          | W.                                      |          |                          |             |   | 4  |
| Vit.—sy.                 | W., Y., P.                              | W.       | Am.                      | Inf.        | s. HCl  | 5  |
| Met.                     | Silver W.                               | W.       | Conch.<br>uneven         | E. fus.     | E.s. HNO <sub>3</sub>                         | 6  |
|                          | G.                                      |          |                          |             |   | 7  |
| Wax                      | Y.—W.                                   | W.       | Conch.                   | Burns.      | Ins.  | 8  |
| Vit. py.                 | W., G.                                  | W.       | oP.                      | E. fus.     | d.s. H <sub>2</sub> SO <sub>4</sub>           | 9  |
| Pleochroi                | c).                                     |          |                          | 8           |   | 10 |
| Vit.                     | Purple                                  | W.       | Conch.                   | Inf.        | Ins.  | 11 |
| Vit.                     | Purple                                  | W.       | Cryst. or<br>conch.      | Inf.        | sol. HF                                       | 12 |
|                          |   |          |                          |             |   | 13 |
| Vit., res., or<br>earthy | G., Gr., Bl.                            | Gr., G.  | ∞ P. 124°                | E. fus.     | gelatinous SiO <sub>2</sub><br>with HCl       | 14 |
|                          |   |          |                          |             |   | 15 |
| Vit.                     | W., tr., tl., or<br>op.                 | W.       | Sub. conch.<br>or uneven | 2·5         | gelatinous SiO <sub>2</sub><br>with HCl       | 16 |
| ad. met.                 | G., Br., Bl., B.                        | Gr., W.  | oP, P.                   | Inf.        | Ins.  | 17 |
| Vit.                     | Gr., P., Br.                            | W.       | Uneven,<br>tough         | Inf.        | E.s. H <sub>2</sub> SO <sub>4</sub><br>and HF | 18 |
| Vit.                     | C., W., G.                              | W.       |                          | 4           | Ins.  | 19 |
|                          |   |          |                          |             |   | 20 |
| Ad. res. or<br>vit.      | Wine Y.<br>W. tinted Y.,<br>R., B., Gr. | C.       | Conch. v.<br>brittle     | E. fus.     | d.s. HCl,<br>s. KOH                           | 21 |
| Py. or vit.              | W.                                      | Gr., W.  | Uneven and<br>splintery  | 3·5         | d.s. H <sub>2</sub> O,<br>s. HCl              | 22 |
| Vit.                     | Y., Gr., Br.                            | Y., W.   | Brittle                  | Inf.        | s. HCl  | 23 |
| Matt.                    | G. (apple), W.                          | G., W.   | Earthy                   | E. fus.     | E.s. HCl                                      | 24 |
| Met.                     | Bl.                                     | Bl.      | Conch.                   | Inf.        |   | 25 |
|                          |   |          |                          |             |   | 26 |
| Vit. py.                 | W., C., and<br>milky                    | C., W.   | Conch.                   | 3           | s. conc. HCl                                  | 27 |
| Vit.                     | C., W., R.                              | C.       | oP, ∞P <sup>∞</sup>      | 4           | Ins.  | 28 |
| Vit. py.                 | Br., Gr.                                | Br., W.  | ∞P <sup>∞</sup>          | 5           | Ins.  | 29 |
| Vit. sub.—<br>met., res. | Bl.                                     | Bl., Gr. | Conch.<br>uneven         | Burns       | Ins.  | 30 |
| Earthy                   | Gr., Br.                                | Gr.      | Conch.                   | Inf.        | s. HCl  | 31 |
|                          |   |          |                          |             |   | 32 |
| Met.                     | Tin W.                                  | Tin W.   | Very cryst.              | 1—1·5       | s. hot HCl<br>SbCl <sub>3</sub> separates     |    |
| Met.                     | Lead Gr.                                | Gr.      | Sectile                  | 1           | s. hot HCl                                    | 33 |

| Name.                              | Composition.   | Cryst.<br>System. | Specific<br>Gravity. | Hardness |
|------------------------------------|--|-------------------|----------------------|----------|
| 1 Antimonate,<br>Calcium (Romeite) | $3\text{CaO} \cdot \text{Sb}_2\text{O}_3$  | II.               |                      |          |
| 2 - Copper (Rivotite)              | $3\text{CuO} \cdot \text{Sb}_2\text{O}_3 + \text{CuCO}_3$  | II.               |                      |          |
| 3 - Lead                           | (Several exist, of varying composition, some contain-  |                   |                      |          |
| 4 Antimonious nickel               | $\text{NiSb}$  | III.              | 7.5                  | 5.5      |
| 5 Antimony ochre                   | $\text{Sb}_2\text{O}_3$  | ?                 | 3.7—3.8              | 1        |
| 6 Antimonial<br>nickel-sulphide    | See Ullmannite.  |                   |                      |          |
| 7 Antimonial silver                | See Dyscrasite.  |                   |                      |          |
| 8 Apatite                          | $3(\text{Ca}_3\text{P}_2\text{O}_8) + \text{CaCl}_2$<br>(Cl variety)<br>$3(\text{Ca}_3\text{P}_2\text{O}_8) + \text{CaF}_2$<br>(F variety) | III.              | 2.92—3.25            | 5        |
| 9 Aphanesite                       | $2\text{CuO} \cdot \text{As}_2\text{O}_3 + 4\text{H}_2\text{O}$  | IV.               | 4.19—4.36            | 2.5—3    |
| 10 Aplome                          | See Garnet, Iron-lime.   |                   |                      |          |
| 11 Apophyllite                     | $\text{K}_2\text{O} \cdot 8\text{CaO} \cdot 16\text{SiO}_2$<br>$16\text{H}_2\text{O}$  | II.               | 2.3—2.4              | 4.5—5    |
| 12 Aquamarine                      | See Beryl.   |                   |                      |          |
| 13 Aragonite                       | $\text{CaCO}_3$  | IV.               | 2.93                 | 3.5—4    |
| 14 Arendalite                      | See Epidote. Fine crystallised form.   |                   |                      |          |
| 15 Arvedsonite                     | Amphibole with soda  | V.                |                      |          |
| 16 Argentine                       | See Calcite (Lamellar, white, shining variety)   |                   |                      |          |
| 17 Argentite                       | $\text{Ag}_2\text{S}$  | I.                | 7.10—7.36            | 2—2.5    |
| 18 Argentopyrites                  | $3\text{FeS} \cdot 3\text{FeS}_2 \cdot \text{Ag}_2\text{S}$  | IV.               | 6.47                 | 3.5—4    |
| 19 Arkansite                       | See Brookite (Thick iron-black crystals).  |                   |                      |          |
| 20 Arsenate of Cobalt              | See Erythrine.   |                   |                      |          |
| 21 - Copper                        | $2\text{CuO} \cdot \text{As}_2\text{O}_3 + 4\text{H}_2\text{O}$  | IV.               | 3.4                  | 3.5      |
| 22 - Iron                          | $2\text{FeO} \cdot \text{As}_2\text{O}_3$  | IV.               | 3.1—3.3              | 3.5—4    |
| 23 - Lead                          | See Minetite.  |                   |                      |          |
| 24 - Zinc                          | See Adamine.   |                   |                      |          |
| 25 Arsenic (Native)                | As.  | III.r.            | 5.93                 | 3.5      |
| 26 - (White)                       | $\text{As}_2\text{O}_3$  | I.                | 3.7                  | 1.5      |
| 27 Arsenical Antimony              | $\text{Sb}_2\text{As}_3$   | IV.               | Also known as        |          |
| 28 - cobalt                        | See Smaltine   |                   |                      |          |
| 29 - iron ore                      | See Mispickel  |                   |                      |          |
| 30 - lead ores                     | See Freislebenite.   |                   |                      |          |
| 31 - nickel                        | See Kupfernickel   |                   |                      |          |
| 32 Arsenical iron<br>(Löllingite)  | $\text{FeAs}_2$  | IV.               | 7—7.4                | 5—5.5    |
| 33 Arsenical pyrites               | See Mispickel.   |                   |                      |          |
| 34 Arsenolite                      | See Arsenic (White)  |                   |                      |          |
| 35 Arsenopyrites                   | See Mispickel.   |                   |                      |          |
| 36 Asbestos                        | Fibrous Actinolite,<br>Grammatite, and<br>Tremolite  | V.                | 2.9                  |          |
| 37 Asbolane                        | See Earthly Cobalt.  |                   |                      |          |
| 38 Asparagus Stone                 | See Apatite (Pale yellowish-green variety).  |                   |                      |          |
| 39 Asphaltum                       | 75%—88% C. Mixture of hydrocarbons,<br>partly oxidised)  | Am.               | 1—1.7                | 1—2      |

| Lustre.      | Colour.                                | Streak.        | Fracture.                           | Fusibility. | Solubility.  |    |
|--------------|--|----------------|-------------------------------------|-------------|--|----|
| Earthy       | Y.                                     | Y.             |                                     | 3—4         |  | 1  |
| ing chlorine | Y.—G.                                  | G.             |                                     |             |  | 2  |
| Met.         | and some silic                         | a.)            |                                     |             |  | 3  |
| Dull         | Copper R.                              | P.             | Cryst.                              | d, fus.     | E.s. HNO <sub>3</sub>  | 4  |
|              | Y.                                     | Y.             | Earthy                              | Inf.        | s. hot HCl   | 5  |
|              |  |                |                                     |             |  | 6  |
|              |  |                |                                     |             |  | 7  |
| Vit. or res. | W., C., tr. G.,<br>Br., B., op.        | W.             | Conch.<br>brittle                   | 1—5         | s. HCl   | 8  |
|              |  |                |                                     |             |  |    |
| Vit.         | Dark G.—B.                             | G.             | Conch.<br>uneven                    | fus.        | s. HNO <sub>3</sub>  | 9  |
|              | R.                                     |                |                                     |             |  | 10 |
| Vit. or py.  | W., C., G., Gr.,<br>Y., R., tr. or tl. | C.             | oP                                  | 3           | gelatinous SiO <sub>2</sub><br>with HCl                                | 11 |
|              | Pale B.                                |                |                                     |             |  | 12 |
| Vit.         | C., W., Y., P.,<br>Gr.,<br>Bl., G.     | C.             | Conch.<br>brittle                   | Inf.        | E.s. HCl   | 13 |
|              |  |                |                                     |             |  | 14 |
|              |  |                |                                     |             |  | 15 |
|              |  |                |                                     |             |  | 16 |
| Met.         | Bl., Lead Gr.                          | Gr.<br>shining | sub. conch.<br>or uneven<br>sectile | Fus.        | s. HNO <sub>3</sub>  | 17 |
| Met.         | W., Y., Br.                            | Bl.            | oP                                  | E. fus.     | decom. HNO <sub>3</sub>  | 18 |
|              |  |                |                                     |             |  | 19 |
|              |  |                |                                     |             |  | 20 |
| Vit.         | G.                                     | G.             | Conch.                              | E. fus.     | s. HNO <sub>3</sub>  | 21 |
| Vit.—ad.     | Leek G. or<br>liver Br.                | G.             | Conch.                              | Fus.        | s. HNO <sub>3</sub>  | 22 |
|              |  |                |                                     |             |  | 23 |
|              |  |                |                                     |             |  | 24 |
| Met.         | W. tarnishes<br>Gr.                    | Tin W.         | Uneven,<br>granular,<br>brittle     | Volatilises | s. HNO <sub>3</sub> with<br>sepn. of<br>As <sub>2</sub> O <sub>3</sub> | 25 |
| Dull         | W.                                     | C.             | Earthy.                             | Volatilises | D.s. H <sub>2</sub> O  | 26 |
| Allemontite. |  |                |                                     |             |  | 27 |
|              |  |                |                                     |             |  | 28 |
|              |  |                |                                     |             |  | 29 |
|              |  |                |                                     |             |  | 30 |
|              |  |                |                                     |             |  | 31 |
| Met.         | W., Gr.                                | BL             | oP                                  | d. fus.     | s. HNO <sub>3</sub> with<br>sepn. of As <sub>2</sub> O <sub>3</sub>    | 32 |
|              |  |                |                                     |             |  | 33 |
|              |  |                |                                     |             |  | 34 |
|              |  |                |                                     |             |  | 35 |
| Sy.          | W., G., Y., Br.                        |                | Fibrous                             | d. fus.     | d. decomp.   | 36 |
|              |  |                |                                     |             |  | 37 |
|              |  |                |                                     |             |  | 38 |
| Oily         | Br., Bl.                               | Bl.            | Conch.                              | 100° C.     | s. ether   | 39 |



| Name.                       | Composition.  | Cryst. System.            | Specific Gravity. | Hardness. |
|-----------------------------|---|---------------------------|-------------------|-----------|
| 1 Astrachanite              | See Blödite.  |                           |                   |           |
| 2 Astrophyllite             | $(\text{Fe}, \text{Mn})_4(\text{Na}, \text{K}, \text{H})_4(\text{Si}, \text{Ti}, \text{Zr})_6\text{O}_{16}$   | IV.                       | 3.3—3.4           | 3.5       |
| 3 Atacamite                 | $\text{CuCl}_2 + \frac{1}{3}\text{Cu}(\text{OH})_2$   | IV. pris.                 | 3.76—4.3          | 3—3.5     |
| 4 Auerbachite               | $\text{ZrSiO}_4$  | Am.                       |                   |           |
| 5 Augite                    | $\text{CaO} \cdot \text{MgO} \cdot 2\text{SiO}_2$ with $(\text{Mg}, \text{Fe})\text{O} \cdot (\text{Al}, \text{Fe})_2\text{O}_3 \cdot \text{SiO}_2$ . A pyroxene. | V.                        | 3.2—3.5           | 6         |
| 6 Aurichalcite              | $2(\text{Zn}, \text{Cu})\text{CO}_3 \cdot 3(\text{Zn}, \text{Cu})(\text{OH})_2$   | ?                         | 3.43—3.6          | 2         |
| 7 Automolite                | $\text{ZnO} \cdot \text{Al}_2\text{O}_3$  | I.                        | 4—4.6             | 7.5—8     |
| 8 Autunite                  | $(\text{CaO} + 3\text{U}_2\text{O}_3)\text{P}_2\text{O}_5 + 8\text{H}_2\text{O}$  | IV.                       | 3.05—3.19         | 2—2.5     |
| 9 Aventurine Felspar        | See Felspar (Minute di  | seminated                 | crystals of       | specular  |
| 10 — Quartz                 | $\text{SiO}_2$ with spangles of golden-yellow or brown mica   | III. rh.                  | 2.5—2.8           | 7         |
| 11 Axinite                  | $\text{H}_2(\text{CaFeMn})_4(\text{BO})\text{Al}_3(\text{SiO}_4)_3$   | VI.                       | 3.27              | 6.5—7     |
| 12 Azorite                  | $\text{ZrSiO}_4$  | II.                       |                   |           |
| 13 Azurite                  | $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$   | V.                        | 3.5—3.8           | 3.5—4.25  |
| 14 Babingtonite             | $(\text{Ca}, \text{Fe}, \text{Mn})\text{O} \cdot \text{SiO}_2$ ; $\text{Fe}_2\text{O}_3 \cdot 3\text{SiO}_2$  | VI.                       | 3.3—3.4           | 5—5.5     |
| 15 Baddeleyite (Brazillite) | $\text{ZrO}_2$ (96.5%) contg. $\text{Al}, \text{Fe}, \text{Mg}, \text{K}, \text{Na}, \text{Si}$   | V.                        | 5—6               | 6.5       |
| 16 Bagrationite (Allanite)  | Cerium epidote  | V.                        | 3—4.2             | 5.5—6     |
| 17 Baikalite                | See Diopside  |                           |                   |           |
| 18 Balas Ruby               | See Spinel.   |                           |                   |           |
| 19 Barcenite                | $3\text{HgO} \cdot \text{Sb}_2\text{O}_3$   | Am.                       | 5.343             | 5.5       |
| 20 Barylite                 | $2\text{BaO} \cdot \text{SiO}_2$  | Am.                       | 4.03              | 7         |
| 21 Barytes                  | $\text{BaSO}_4$   | IV.                       | 4.3—4.7           | 2.5—3.5   |
| 22 Baryto-Calcite           | See Alstonite.  |                           |                   |           |
| 23 Basanite                 | See Jasper (used for  | streak plates for testing | gold al           |           |
| 24 Bastite                  | See Schillerspar.   |                           |                   |           |
| 25 Bastnäsite (Hamartite)   | $[(\text{Ce}, \text{La}, \text{Di})\text{F}]\text{CO}_2$  | III.                      | 4.93—5.18         | 4—4.5     |
| 26 Beauxite                 | $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$   | Am.                       |                   |           |
| 27 Beccarite                | $\text{ZrO}_2$  |                           |                   | 8         |
| 28 Bell-metal ore           | See Stannine.   |                           |                   |           |
| 29 Beryl                    | $3\text{BeO} \cdot \text{SiO}_2 + \text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2$  | VI.                       | 2.63—2.75         | 7.5—8     |
| 30 Beyrichite               | See Millerite   | III. rh. h.               |                   |           |
| 31 Bieberite                | $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$   | VI.                       |                   |           |
| 32 Binnite                  | $2\text{As}_2\text{S}_3 \cdot 3\text{Cu}_2\text{S}$   | Itetr. h.                 |                   |           |
| 33 Biotite                  | $(\text{K}, \text{H})_2\text{O} \cdot (\text{Mg}, \text{Fe})_2\text{O}_3 \cdot \text{Al}_2\text{O}_3$   | V.                        | 2.7—3.2           | 2.5—3     |
| 34 Bismite                  | See Bismuth Ochre.  | V.                        |                   |           |
| 35 Bismuth, Native          | Bi  | III. rh.                  | 9.7—9.8           | 2—2.5     |



| Lustre.       | Colour.                            | Streak.      | Fracture.                        | Fusibility. | Solubility.                          |        |
|---------------|------------------------------------|--------------|----------------------------------|-------------|--------------------------------------|--------|
| Vit.          | Br. Y., Y.,<br>R. Br.              | Pale Br.     | $\infty P_{\infty}$              | E. fus.     |                                      | 1      |
| Ad.—vit.      | G.—Bl. G.,<br>bl.—stl.             | Apple G.     | $\infty P_{\infty}$              | Fus.        | s. $HNO_3$                           | 2<br>3 |
| Earthy        | Br., Gr.                           | Br.          |                                  |             |                                      | 4      |
| Vit.—res.     | Bl. & G. Bl.                       | W., Gr.      |                                  | 3·5         | de. decomp.                          | 5      |
| Py.           | Pale G.—sky B.                     | B., W.       |                                  | Inf.        | s. HCl                               | 6      |
| Vit.          | Dark G.—Bl.                        | G.           | Conch.                           | Inf.        | Ins.                                 | 7      |
| Sub. ad.      | Citron-<br>sulphur Y.              | Y. W.        | $\infty P$ ; $\infty P_{\infty}$ | E. fus.     | s. $HNO_3$                           | 8      |
| or titanite   | iron or limoni                     | (te).        |                                  |             |                                      | 9      |
| Vit.          | C. tl.                             | C.           | Conch.                           | Inf.        | s. HF                                | 10     |
| Highly vit.   | Clove Br.,<br>plum Br.,<br>py. Gr. | C.           | $\infty P_{\infty}$              | 2           | Gelatinous<br>$SiO_2$ with<br>HCl.   | 11     |
| Ad. vit.      | Gr. G.                             |              |                                  |             |                                      | 12     |
| Vit.—sub.     | Azure B.,                          | Light B.     | $P_{\infty}$                     | 2           | S. HCl.                              | 13     |
| ad.           | tr.—op.                            |              |                                  |             |                                      |        |
| Vit.          | G. Bl.                             | G. Gr.       | $\infty P$ ; $\infty P_{\infty}$ | E. fus.     | Ins.                                 | 14     |
| Fatty, sy.    | Y., Br., Bl.                       | Br., W.      | Conch.                           |             |                                      | 15     |
| Sub. met.     | Bl.—pinch-                         | Br.          | uneven<br>Cryst.                 | E. fus.     | Gelatinous<br>$SiO_2$ with<br>HCl.   | 16     |
| —res.         | beck Br.                           |              |                                  |             |                                      | 17     |
|               | Rose R.                            |              |                                  |             |                                      | 18     |
| Earthy        | Gr. Bl.                            | Gr.          | Earthy                           | E. fus.     | Sol. $HNO_3$                         | 19     |
| Earthy        | C.                                 | C.           | Earthy                           | Inf.        |                                      | 20     |
| Vit. res. py. | W., C.                             | W.           | $\infty P$ ; $\infty P_{\infty}$ | 5           | S. hot $H_2SO_4$                     | 21     |
|               |                                    |              |                                  |             |                                      | 22     |
| loys)         | Pure Bl.                           |              |                                  |             |                                      | 23     |
|               |                                    |              |                                  |             |                                      | 24     |
| Vit.          | Y., R. Br.                         | Y. Gr.       |                                  | Inf.        | Decomp. HCl.                         | 25     |
| Earthy        | W., Gr., Br.,<br>R., Y.            | W., Br.      | Earthy                           | Inf.        | d.s. hot HCl<br>and hot<br>$H_2SO_4$ | 26     |
| Vit.          | Olive G.                           | G.           |                                  | Inf.        | Ins.                                 | 27     |
|               |                                    |              |                                  |             |                                      | 28     |
| Vit. res.     | G., B., Y., W.                     | W.           | Conch.<br>brittle                | 5·5         | Ins.                                 | 29     |
|               |                                    |              |                                  |             |                                      | 30     |
| Vit.          | Flesh or rose<br>R.                | P.           | Conch.                           |             |                                      | 31     |
| Met.          | Gr. Bl.                            | Br.          | Conch.                           | E. fus.     | Decomp. hot<br>HCl. and<br>KOH       | 32     |
| Py. spler-    | Bl., G., Br.,<br>R.                | C.           | $\infty P$                       | D. fus.     | Decomp.<br>$H_2SO_4$                 | 33     |
| dent          |                                    |              |                                  |             |                                      | 34     |
| Met.          | Silver W.,<br>P. tinge             | As<br>colour | $\infty R$ —2R<br>sectile        | 1           | s. $HNO_3$                           | 35     |

| Name.                     | Composition.   | Cryst.<br>System.  | Specific<br>Gravity. | Hardness.          |
|---------------------------|--|--------------------|----------------------|--------------------|
| 1 Bismuth Nickel          | $\text{Bi}_2\text{S}_3$ with $\text{NiS}$                                      | III.               | 5.13                 | 4.5                |
| 2 — Ochre                 | $\text{Bi}_2\text{O}_3$  | IV. or Am.         | 4.36                 | 1.5                |
| 3 — silver                | Ag with 16% Bi; $\text{Ag}_2\text{Bi}$   |                    |                      |                    |
| 4 — gold                  | $\text{Au}_2\text{Bi}$   |                    | 8.2—8.7              | 2                  |
| 5 — Telluride             | See Tetradymite.   |                    |                      |                    |
| 6 Bismuthinite            | $\text{Bi}_2\text{S}_3$  | Acicular crystals. |                      |                    |
| 7 Bismuthite—ine          | $\text{Bi}_2\text{S}_3$  | IV.                | 6.5                  | 2—2.5              |
| 8 Bitter Spar             | See Dolomite (ferruginous variety).  |                    |                      |                    |
| 9 Bitumen                 | Hydrocarbons, partly oxygenated  | See Asphaltum.     |                      |                    |
| 10 — elastic              | As for Bitumen   | Am,                | 0.9—1.25             | 0.5                |
| 11 Black cobalt           | See Earthy Cobalt,   |                    |                      |                    |
| 12 Black jack             | See Sphalerite.  |                    |                      |                    |
| 13 — lead                 | See Graphite.  |                    |                      |                    |
| 14 — silver               | See Stephanite   |                    |                      |                    |
| 15 — tellurium            | (Pb, Au,)(Te, S)   | II.                | 7.1                  | 1—1.5              |
| 16 Blende                 | See Sphalerite.  |                    |                      |                    |
| 17 Blödit                 | $\text{Na}_2\text{SO}_4 \cdot \text{MgSO}_4 \cdot 4 \text{H}_2\text{O}$        | V.                 | 2.25                 | 2.5—3.5            |
| (Astrachanite)            |  |                    |                      |                    |
| 18 Bloodstone             | See Jasper.  |                    |                      |                    |
| 19 Blue iron ore          | See Vivianite  | Earthy             |                      |                    |
| 20 — copper               | $\text{CuS}$   | Am.                | 3.8                  | 2.5—3              |
| 21 — John                 | See Fluor Spar.  |                    |                      |                    |
| 22 — vitriol              | See Chalcantite.   |                    |                      |                    |
| 23 Boghead coal           | Cannel coal, high % ash.   | Am.                | 1.4—1.7              |                    |
| 24 Bog iron ore           | See Limonite   | Am.                |                      |                    |
| 25 Bole                   | $4 \text{Al}_2\text{O}_3 \cdot 9 \text{SiO}_2$                                 | Am.                | 1.6—2.2              | 1—2                |
| 26 Bone turquoise         | Fossil bones or teeth, coloured with $\text{Fe}_3\text{P}_2\text{O}_8$         |                    |                      |                    |
| 27 Boracic acid           | $3 \text{H}_2\text{O} \cdot \text{B}_2\text{O}_3$                              | VI.                | 1.48                 | 1                  |
| 28 Boracite               | $6 \text{MgO} \cdot \text{MgCl}_2 \cdot 8 \text{B}_2\text{O}_3$                | I. or Am.          | 2.95                 | 4—5, o. crystals 7 |
| 29 Borax                  | $\text{Na}_2\text{O} \cdot 2 \text{B}_2\text{O}_3 \cdot 10 \text{H}_2\text{O}$ | V. pris.           | 1.74                 | 2—2.5              |
| 30 Borate, calcium-sodium | See Ulexite.   |                    |                      |                    |
| 31 — magnesium            | See Boracite.  |                    |                      |                    |
| 32 Bornite                | $2 \text{Cu}_3\text{S} \cdot \text{Cu}_3\text{S}_2 \cdot 2 \text{FeS}$         | I                  | 4.9—5.4              | 3                  |
| 33 Boronatrocalcite       | See Ulexite.   |                    |                      |                    |
| 34 Bort                   | C, (compact variety of diamond, used for cutting precious stones)              |                    |                      |                    |
| 35 Botryolite             | See Datolite (Botryoidal).   |                    |                      |                    |
| 36 Boulangerite           | $3 \text{PbS} \cdot \text{Sb}_2\text{S}_3$                                     | IV.                | 5.8—6                | 3                  |
| 37 Bournonite             | $3 (\text{Pb}, \text{Cu})_2\text{S} \cdot \text{Sb}_2\text{S}_3$               | IV.                | 5.7—5.9              | 2.5—3              |
| 38 Bowenite               | Serpentine   |                    | 2.59—2.8             | 5.5—6              |

| Lustre.            | Colour.                        | Streak.           | Fracture.             | Fusibility.   | Solubility.   |    |
|--------------------|--------------------------------|-------------------|-----------------------|---------------|---|----|
| Met.               | Gr.—W.                         | W.                | Conch.                | Fus.          | s.HNO <sub>3</sub>  | 1  |
| Waxy or Earthy     | Gr., Y., G.                    | Y., W.            | Earthy                | Fus.          | s.HNO <sub>3</sub>  | 2  |
| Met.               | W.                             | Met. W.           |                       | E. fus.       | s.HNO <sub>3</sub>  | 3  |
| Met.               | Y., W.                         | Met. Y., W.       |                       | E. fus.       | s.Aqua-regia  | 4  |
|                    |                                |                   |                       |               |   | 5  |
| Met.               | Lead Gr.                       | W., Gr.           | Earthy                |               |   | 6  |
|                    | Lead Gr., Y.                   | Gr., Bl.          | ∞ P ∞                 | E. fus.       | s.HNO <sub>3</sub> with sepn. of S.                                   | 7  |
|                    |                                |                   |                       |               |   | 8  |
| Pitchy             | Bl., Br.                       | Bl.               | Elastic               | E. fus. burns |   | 9  |
|                    |                                |                   |                       |               |   | 10 |
|                    |                                |                   |                       |               |   | 11 |
|                    |                                |                   |                       |               |   | 12 |
|                    |                                |                   |                       |               |   | 13 |
|                    |                                |                   |                       |               |   | 14 |
| Met.               | Gr.                            | Gr., Bl.          | ∞ P ∞                 | E. fus.       | s.HNO <sub>3</sub> with sepn. of Au.                                  | 15 |
| Vit.               | C., G., Gr. P.                 | C.                |                       | Fus.          | E.s.H <sub>2</sub> O  | 16 |
|                    | G. with R. spots               |                   |                       |               |   | 17 |
|                    |                                |                   |                       |               |   | 18 |
| Dull               | Bl.—B.                         | Dark B.           | Earthy                | E. fus.       | s.hot HNO <sub>3</sub> with sepn. of S.                               | 19 |
|                    |                                |                   |                       |               |   | 20 |
|                    |                                |                   |                       |               |   | 21 |
| Waxy               | Bl.                            |                   |                       | Burns         | Ins.  | 22 |
|                    | Br., Bl.                       |                   | Earthy, loose         |               |   | 23 |
|                    |                                |                   | Conch.                |               |   | 24 |
| Earthy             | Br., Gr. B.                    | Gr. W.            |                       | Inf.          |   | 25 |
|                    |                                |                   |                       |               |   | 26 |
| Py., TL, Tr.       | C., W. Gr.                     | W.                | oP                    | 2             | E.s.hot H <sub>2</sub> O  | 27 |
| Vit.               | C., W., Y., Gr. G., Tr. or op. | W.                | Conch.                | 2             | d.s.HCl   | 28 |
| Vit. or earthy     | W., tinge B. G., Gr.           | W.                | Soft, brittle         | E. fus.       | s.H <sub>2</sub> O  | 29 |
|                    |                                |                   |                       |               |   | 30 |
| Met.               | Copper R. or pinchbeck Br.     | Gr., Bl., shining | Conch., uneven, small | 2—3           | s.HNO <sub>3</sub> with sepn. of S.                                   | 31 |
|                    |                                |                   |                       |               |   | 32 |
| ious stones        | and drilling rocks)            |                   |                       |               |   | 33 |
|                    |                                |                   |                       |               |   | 34 |
|                    |                                |                   |                       |               |   | 35 |
| Sy. met.           | Lead Gr.                       | Gr., Bl.          | Uneven                | 1.5—2         | s.hot HCl.  | 36 |
| Met.               | Lead Gr., Bl.                  | Gr.               | Conch. brittle        | 1.5           | s.HNO <sub>3</sub> with sepn. of S and Sb <sub>2</sub> O <sub>3</sub> | 37 |
| Aspect of Nephrite |                                |                   |                       |               |   | 38 |

| Name.                 | Composition.   | Cryst.<br>System.      | Specific<br>Gravity. | Hardness. |
|-----------------------|--|------------------------|----------------------|-----------|
| 1 Braunite            | $Mn_2O_3$  | II.                    | 4.71—4.82            | 6—6.5     |
| 2 Bravaisite          | Near Glauconite  |                        |                      | 1—2       |
| 3 Breithauptite       | See Antimonious Nickel   | el.                    |                      |           |
| 4 Brewsterite         | $(Ba, Sr)O \cdot Al_2O_3 \cdot 6 SiO_2$<br>+ 5 $H_2O$                          | V.                     | 2.45                 | 4.5—5     |
| 5 Brittle silver ore  | See Stephanite.  |                        |                      |           |
| 6 Brochantite         | $CuSO_4 \cdot 3 Cu(OH)_2$  | IV.                    | 3.8—3.9              | 3.5—4     |
| 7 Bröggerite          | $(U, Th, Pb)_3O_6 \cdot 2 UO_3$  | I.                     | 8.7—9                | 5.5       |
| 8 Bromargyrite        | See Bromite.   |                        |                      |           |
| 9 Bromite (Bromyrite) | AgBr   | I.                     | 5.8—6                | 2—3       |
| 10 Bromlite           | See Alstonite  | IV.                    |                      |           |
| 11 Bronzite           | $(Mg, Fe)O \cdot SiO_2$  | IV.                    | 3.18—3.3             | 5.5       |
| 12 Brookite           | $TiO_2$  | IV.                    | 3.8—4.2              | 5.5—6     |
| 13 Brown coal         | See Lignite.   |                        |                      |           |
| 14 Brown hematite     | See Limonite.  |                        |                      |           |
| 15 — ochre            | See Limonite.  | Am.                    |                      |           |
| 16 — spar             | Dolomite with $Mn_2O_3$ ,<br>$Fe_2O_3$   | III. rh.               |                      |           |
| 17 Brucite            | $MgO \cdot H_2O$   | III. rh.               | 2.35                 | 2         |
| 18 Bucholzite         | See Fibrolite.   |                        |                      |           |
| 19 Bunsenine          | See Krennerite.  |                        |                      |           |
| 20 Bytownite          | Near Anorthite, more<br>silica (46—48%) and<br>some soda                       | VI.                    | 2.75                 | 6         |
| 21 Cacozenite         | $Fe_2O_3 \cdot P_2O_5 + 8 H_2O$  | V.                     | 3.38                 | 3—4       |
| 22 Cairngorm          | $SiO_2$  | III. rh.               | 2.5—2.8              | 7         |
| 23 Calamine*          | $ZnCO_3$   | III. rh.               | 4—4.45               | 5         |
| 24 Calaverite         | $AuTe_2$   |                        | 9.048                | 1.5—2     |
| 25 Calcite            | $CaCO_3$   | III. rh.               | 2.6—2.7              | 2.5—3.5   |
| 26 Calc-spar          | See Calcite.   |                        |                      |           |
| 27 Caledonite         | $(Pb, Cu)O \cdot (Pb, Cu)SO_4$ ,<br>$H_2O$ .                                   | V.                     | 6.4                  | 2.5—3     |
| 28 Calomel            | $Hg_2Cl_2$   | II.                    | 6.5                  | 1—2       |
| 29 Cancrinite         | $(Na_2, K_2)_4O_4 \cdot 4 Al_2O_3$ ,<br>9 $SiO_2$ with $Na_2CO_3$<br>and water | III.                   | 2.4—2.5              | 5—6       |
| 30 Cannel coal        | 0—60% hydro-<br>carbons  | Am.                    | About 1.5            | 1.5—2     |
| 31 Capillary pyrites  | See Millerite.   |                        |                      |           |
| 32 Carbonado          | C. (diamond) (Used   | for cutting purposes.) |                      |           |
| 33 Carbonate, barium  | See Witherite.   |                        |                      |           |
| 34 — bismuth          | See Bismuthite.  |                        |                      |           |
| 35 — copper           | See Malaohite, Azurite.  |                        |                      |           |
| 36 — iron             | See Siderite.  |                        |                      |           |
| 37 — lead             | See Cerussite.   |                        |                      |           |
| 38 — magnesium        | See Magnesite.   |                        |                      |           |
| 39 — manganese        | See Rhodochrosite.   |                        |                      |           |
| 40 — sodium           | See Natron.  |                        |                      |           |
| 41 — strontium        | See Strontianite.  |                        |                      |           |

\*Calamine is taken as the English name. This is the Smithsonite of Dana

| Lustre.                       | Colour.                    | Streak.      | Fracture.                      | Fusibility. | Solubility.                                  |    |
|-------------------------------|----------------------------|--------------|--------------------------------|-------------|--|----|
| Sub —met.<br>matt.            | Br., Bl., Gr.              | Br., Bl.     | Uneven,<br>brittle             | Inf.        | s.HCl.                                       | 1  |
|                               | Gr. —G.                    | (Greasy      | feel)                          |             |  | 2  |
|                               |                            |              |                                |             |  | 3  |
| Vit. or py.                   | C., W., Gr., Y.            | C.           | $\infty P \infty$              | Fus.        | s.HCl. with<br>sepn. of pow-<br>dery $SiO_2$ | 4  |
|                               |                            |              |                                |             |  | 5  |
| Vit.                          | Emerald G.                 | G.           | $\infty P \infty$              | E. fus.     | s.HCl.                                       | 6  |
| Fatty                         | Bl., G Bl.,<br>Gr. Bl.     | Br., Bl.     | Conch.,<br>uneven              | Inf.        | s.hot $HNO_3$                                | 7  |
|                               |                            |              |                                |             |  | 8  |
| Ad. or fatty                  | G., Y., Gr.                | Y., G.       | Conch.                         | 2           | s. $NH_3$ soln.                              | 9  |
|                               |                            |              |                                |             |  | 10 |
| Met.                          | Br., Y.                    |              | $\infty P \infty$ , $\infty P$ | 6           | Ins.   | 11 |
| Met.—ad.                      | Rov. hair Br.              | Br., Y.      | Uneven                         | Inf.        | Ins.   | 12 |
|                               |                            |              |                                |             |  | 13 |
|                               |                            |              |                                |             |  | 14 |
|                               | Br., Y.                    |              | Earthy                         |             |  | 15 |
|                               | Br.                        |              |                                |             |  | 16 |
| Vit. py.,<br>Wax. or sy.      | G., W., G.<br>Te.—stl.     | W.           | oR                             | Inf.        | s.HCl.                                       | 17 |
|                               |                            |              |                                |             |  | 18 |
|                               |                            |              |                                |             |  | 19 |
| Vit.                          | W.                         |              | $\infty P$ , $\infty P \infty$ | 3·5         | d.decomp.<br>HCl                             | 20 |
|                               |                            |              |                                |             |  |    |
| Sy.                           | Y.—Br.                     | Y.           | Conch.                         | E. fus.     | s.HCl.                                       | 21 |
| Vit.                          | Smoky Y. or Br.            |              | Conch.                         | Inf.        |  | 22 |
| Vit. py.                      | W. (G. or Br.)             | W.           | Uneven,<br>brittle             | Inf.        | s.Acids                                      | 23 |
|                               |                            |              |                                |             |  |    |
| Met.                          | Bronze Y.                  | Y.           | Conch.                         | E. fus.     |  | 24 |
| Vit. —<br>earthy              | C., W., tint P.<br>Y., Gr. | W. or<br>Gr. | Along cleav-<br>age planes     | Inf.        | s.Acids (acetic<br>acid)                     | 25 |
|                               |                            |              |                                |             |  | 26 |
| Wax                           | B., G., G.                 | G., W.       | $\infty P \infty$              | Inf.        | s. $H_2SO_4$ with<br>sepn. of<br>$PbSO_4$    | 27 |
|                               |                            |              |                                |             |  |    |
| Ad.                           | Gr., Y., W.                |              | Conch.,<br>uneven              | Sublimes    | s. $HNO_3$ + HCl                             | 28 |
| Wax                           | W., Y., P.,<br>B.Gr.       | C.           | Uneven                         | V.E. fus.   | s.acids                                      | 29 |
|                               |                            |              |                                |             |  |    |
| Dull, takes<br>high<br>polish | Bl., Br.                   | Br.          | Conch.                         | Burns       |  | 30 |
|                               |                            |              |                                |             |  | 31 |
|                               | Bl.                        |              |                                |             |  | 32 |
|                               |                            |              |                                |             |  | 33 |
|                               |                            |              |                                |             |  | 34 |
|                               |                            |              |                                |             |  | 35 |
|                               |                            |              |                                |             |  | 36 |
|                               |                            |              |                                |             |  | 37 |
|                               |                            |              |                                |             |  | 38 |
|                               |                            |              |                                |             |  | 39 |
|                               |                            |              |                                |             |  | 40 |
|                               |                            |              |                                |             |  | 41 |

and others.

|    | Name.                           | Composition.   | Cryst. System. | Specific Gravity. | Hardness   |
|----|---------------------------------|--|----------------|-------------------|------------|
| 1  | Carbonate yttrium               | See Parisite.  |                |                   |            |
| 2  | — zinc                          | See Calamine.  |                |                   |            |
| 3  | Carnallite                      | $MgCl_2 \cdot KCl \cdot 6 H_2O$  | IV. Am.        | 1.6               | 1          |
| 4  | Carnelian                       | Chalcedony, $SiO_2$  | III.rh.        | 2.4               | 7          |
| 5  | Carpholite                      | $(Mn, Fe)O \cdot (Fe, Al)_2O_3 \cdot 2 SiO_2 + 2 H_2O$                     | V.             | 2.7—2.9           | 5          |
| 6  | Cassiterite                     | $SnO_2$  | II.            | 6.4—7.1           | 6—7        |
| 7  | Cat's eye                       | $SiO_2$ (minutely fibrous)   | structure in   | side quartz       | crystals). |
| 8  | Celestine                       | $SrSO_4$   | IV.            | 3.9               | 3—3.5      |
| 9  | Cerargyrite                     | See Horn Silver.   |                |                   |            |
| 10 | Cerite                          | $2(Ca, Fe)O \cdot 3Ce_2O_3 \cdot 6SiO_2 \cdot 3H_2O$<br>Ce = (Ce, La, Di). | IV.            | 4.75—5.1          | 5.5        |
| 11 | Cerussite                       | $PbCO_3$   | IV.            | 6.5               | 3—3.5      |
| 12 | Cervantite                      | $Sb_2O_3$ results from dec   | composition    | of stibnite.      |            |
| 13 | Chabazite                       | $(Ca, Na)_2O \cdot Al_2O_3 \cdot 4 SiO_2 \cdot 6 H_2O$                     | III. rh. h.    | 2.1—2.2           | 4.5—5      |
| 14 | Chalcanthite                    | $CuSO_4 \cdot 5 H_2O$  | VI.            | 2.21              | 2—2.5      |
| 15 | Chalcedony                      | $SiO_2$ (microcrystalline)   | III.           | 2.6—2.65          | 7          |
| 16 | Chalcocite                      | See Redruthite.  |                |                   |            |
| 17 | Chalcolite                      | $CuO \cdot UO_2 \cdot P_2O_5 \cdot 8 H_2O$<br>contg. Ra                    | II.            | 3.4—3.6           | 2—2.5      |
| 18 | Chalcomenite                    | $CuSeO_3 \cdot 2 H_2O$   | V.             | 3.76              |            |
| 19 | Chalcophanite                   | $Mn_2O_3 \cdot ZnO \cdot xH_2O$  | Am. or IV.     | 4.3               | 5—5.5      |
| 20 | Chalcophyllite<br>(Copper mica) | $2 CuO \cdot As_2O_3 + xH_2O$  | Foliated       | 2.43—2.66         | 2          |
| 21 | Chalcopyrite                    | See Copper Pyrites.  |                |                   |            |
| 22 | Chalcotrichite                  | Capillary Cuprite.   |                |                   |            |
| 23 | Chalk                           | $CaCO_3$   | Am.            | Very variable     |            |
| 24 | Chalybite                       | See Siderite.  |                |                   |            |
| 25 | Chamosite                       | $Al_2O_3 \cdot 3 (Fe, Mg)O \cdot 2 SiO_2 \cdot 3 H_2O$                     |                |                   |            |
| 26 | Chert                           | Massive $SiO_2$  | Am.            | 2.6—2.8           |            |
| 27 | Chessylite                      | See Azurite.   |                |                   |            |
| 28 | Chiastolite                     | Andalusite (Crystals, w  | hen cut across | exhibit           | cruciform  |
| 29 | Chloanthite                     | See Smaltine.  |                |                   |            |
| 30 | Chloride, ammonium              | See Sal-Ammoniac.  |                |                   |            |
| 31 | — copper                        | See Atacamite.   |                |                   |            |
| 32 | — lead                          | See Cotunnite, Cromfo  | rdite.         |                   |            |
| 33 | — magnesium                     | See Carnallite.  |                |                   |            |
| 34 | — mercury                       | See Calomel.   |                |                   |            |
| 35 | — potassium                     | See Sylvine.   |                |                   |            |
| 36 | — silver                        | See Horn Silver.   |                |                   |            |
| 37 | — sodium                        | See Salt, Common.  |                |                   |            |
| 38 | Chlorite                        | $4 H_2O \cdot 5 MgO \cdot Al_2O_3 \cdot 3 SiO_2$ (Clinocllore)             | III.rh. or V.  | 2.6—2.8           | 1.5        |

| Lustre.                                | Colour.                                      | Streak.  | Fracture.                | Fusibility.       | Solubility.  |    |
|--|--|----------|--------------------------|-------------------|--|----|
| Greasy,<br>shining<br>Wax              | W., P. or R.                                 | W.       | Conch.                   | 2 Intu-<br>mesces | E.S.H <sub>2</sub> O                                 | 1  |
|  | R. and Br. R.,<br>tl.                        | R.       | Am.                      | Inf.              |  | 2  |
| Sy.                                    | Y., G. Y.                                    |          | Fibrous                  | 3·5               | Ins.   | 3  |
| Ad. brilliant                          | Bl., Br.                                     | W.—Br.   | Sub. conch.<br>or uneven | Inf.              |  | 4  |
| Vit. py.                               | W., tint pale<br>B.                          | W.       | Conch., very<br>brittle  | Fus.              | Ins.   | 5  |
|  | Br., R.                                      | Gr., W.  | Uneven,<br>brittle       | Inf.              | Gelatinous<br>SiO <sub>2</sub> with<br>HCl.          | 6  |
| Ad. vit.                               | C., W., Gr.                                  |          | Conch.                   | Fus.              | s.HNO <sub>3</sub>                                   | 7  |
| Vit.                                   | C., W., P.                                   |          |                          | 3                 | Gelatinous<br>SiO <sub>2</sub> with<br>HCl.          | 8  |
| Vit.<br>Wax                            | B.<br>W., Gr., Br.,<br>Y., R., P.,<br>G., B. | W.<br>W. | Conch.<br>Brittle        | Inf.<br>Inf.      | s.H <sub>2</sub> O<br>s.HF and<br>KOH                | 9  |
| Vit. py.                               | G.   | W. G.    | oP; ∞P∞                  | Fus.              | s.HNO <sub>3</sub>                                   | 10 |
| Vit.                                   | Bright B.                                    | ?        |                          | Fus.              | s.HCl.   | 11 |
| Res.                                   | Bl. Br.                                      | Br.      |                          | Fus.              |  | 12 |
|  | Grass G.                                     | G.       |                          |                   |  | 13 |
| Earthy                                 | Cochineal R.<br>W.                           | W.       | Conch.,<br>earthy        | Inf.              | s.acids  | 14 |
|  | B., G., G. Bl.                               |          |                          | Inf.              | Decomp. with<br>liberation<br>of SiO <sub>2</sub>    | 15 |
| Dull                                   | Gr., Br., Bl.                                | Gr.      | Conch.                   | Inf.              | s.KOH and<br>HF                                      | 16 |
| lozenge shaped or tessellated figures) |  |          |                          |                   |  | 17 |
|  |  |          |                          |                   |  | 18 |
|  |  |          |                          |                   |  | 19 |
|  |  |          |                          |                   |  | 20 |
|  |  |          |                          |                   |  | 21 |
|  |  |          |                          |                   |  | 22 |
|  |  |          |                          |                   |  | 23 |
|  |  |          |                          |                   |  | 24 |
|  |  |          |                          |                   |  | 25 |
|  |  |          |                          |                   |  | 26 |
|  |  |          |                          |                   |  | 27 |
|  |  |          |                          |                   |  | 28 |
|  |  |          |                          |                   |  | 29 |
|  |  |          |                          |                   |  | 30 |
|  |  |          |                          |                   |  | 31 |
|  |  |          |                          |                   |  | 32 |
|  |  |          |                          |                   |  | 33 |
|  |  |          |                          |                   |  | 34 |
|  |  |          |                          |                   |  | 35 |
|  |  |          |                          |                   |  | 36 |
|  |  |          |                          |                   |  | 37 |
| Py. slightly<br>greasy                 | G., Bl., Y.,<br>rose R.                      | W., G.   | oP                       |                   | Decomp.HCl.<br>with floccu-<br>lent SiO <sub>2</sub> | 38 |



| Name.                | Composition.   | Cryst. System. | Specific Gravity. | Hardness |
|----------------------|--|----------------|-------------------|----------|
| 1 Chloritoid         | $\text{Al}_2\text{O}_3 \cdot \text{FeO} \cdot \text{SiO}_2 \cdot \text{H}_2\text{O}$   | V.             | 3.45—3.6          | 6—6.5    |
| 2 Chlormagnesite     | $\text{MgCl}_2$  | IV.            |                   |          |
| 3 Chlorothionite     | $(\text{Cu}, \text{K}_2) (\text{SO}_4, \text{Cl}_2)$   | VI.            |                   |          |
| 4 Chondrodite        | $8 \text{MgO} \cdot 3 \text{SiO}_2$ , iron and fluorine present  | V              | 3.1—3.25          | 6—6.5    |
| 5 Chromate, lead     | See Crocoisite.  |                |                   |          |
| 6 Chrome, ochre      | $\text{SiO}_2 \cdot \text{Al}_2\text{O}_3 \cdot \text{Cr}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$                           | Am.            |                   |          |
| 7 — yellow           | See Crocoisite.  |                |                   |          |
| 8 Chromic iron       | See Chromite.  |                |                   |          |
| 9 Chromite           | $\text{Fe}_2\text{O}_3 \cdot \text{FeO}$ with $\text{CrO}$ and $\text{Cr}_2\text{O}_3$                                       | I.             | 4.32—4.6          | 5.5      |
| 10 Chromium sulphide | $\text{Cr}_2\text{S}_3$ . (From meteorites.)   | tes.)          |                   |          |
| 11 Chrysoberyl       | $\text{BeO} \cdot \text{Al}_2\text{O}_3$   | IV.            | 3.5—3.8           | 8.5      |
| 12 Chrysocolla       | $\text{CuO} \cdot \text{SiO}_2 \cdot 2 \text{H}_2\text{O}$   | Am.            | 2—2.23            | 2—4      |
| 13 Chrysolite        | $2 (\text{Mg}, \text{Fe})\text{O} \cdot \text{SiO}_2$  | IV             | 3.3—3.5           | 6—7      |
| 14 Chrysoprase       | $\text{SiO}_2$ . Chalcedony, with $\text{NiO}$ .   | Am             | 2.64              | 7        |
| 15 Chrysotile        | See Serpentine (fibrous variety)   | III rh         | 8.99              | 2—2.5    |
| 16 Cinnabar          | $\text{HgS}$   | I rh           | 3.5—3.6           | 7—7.5    |
| 17 Cinnamon stone    | See Garnet, Lime-Alumina   |                |                   |          |
| 18 Citrine           | See Quarz. $\text{SiO}_2$  |                |                   |          |
| 19 Claudetite        | $\text{As}_2\text{O}_3$  | IV.            |                   |          |
| 20 Clausthalite      | $\text{PbSe}$  | I.             | 8.2—8.8           | 2.5—3    |
| 21 Clay ironstone    | See Limonite (Limonite in nodular forms, Argillaceous)   | Am. IV. rh.    | 2.4—2.6           | 1—2.5    |
| 22 Clay              | Variable.  |                |                   |          |
| 23 Cleavelandite     | Lamellar Albite  |                |                   |          |
| 24 Cleveite          | Hydrated $\text{UO}_3$ , contg. V, Er, Ce, Th, A, He   | I.             | 7.49              | 5.5      |
| 25 Clinkstone        | See Phonolyte  |                |                   |          |
| 26 Clinocllore       | See Chlorite.  |                |                   |          |
| 27 Clinoclase        | See Aphanesite.  |                |                   |          |
| 28 Clintonite        | $10 (\text{Mg}, \text{Ca}, \text{Fe})\text{O} \cdot 5 \text{Al}_2\text{O}_3 \cdot 4 \text{SiO}_2 \cdot 3 \text{H}_2\text{O}$ | V              | 3.1               | 4—5      |
| 29 Coal—Mineral      | About 82.85% fixed C.  | Am.            | 1.57—1.67         | 2—2.5    |
| 30 — brown           | Less C than above, More O and $\text{H}_2\text{O}$   | Am.            | 1.2—1.5           | 1—2      |
| 31 Cobalt            | Does not occur native.   |                |                   |          |
| 32 — bloom           | See Erythrine.   |                |                   |          |
| 33 — glance          | See Smaltine.  |                |                   |          |
| 34 — vitriol         | See Bieberite.   |                |                   |          |
| 35 Cobaltine         | $\text{CoAsS}$ ( $\text{CoS}_2 + \text{CoAs}_2$ )  | I.             | 6.63              | 5.5      |
| 36 Cocolite          | Augite   | Am.            | 3.25—3.3          | 5—6      |
| 37 Colemanite        | $2 \text{CaO} \cdot 3 \text{B}_2\text{O}_3 \cdot 5 \text{H}_2\text{O}$   | V.             | 2.43              | 4—4.5    |



| Lustre.               | Colour.                                       | Streak.            | Fracture.                        | Fusibility  | Solubility                                     |    |
|-----------------------|---|--------------------|----------------------------------|-------------|--|----|
| Vit. wax              | Bl. G., G.                                    | W., G              | oP                               | d.fus.      | Decomp<br>$H_2SO_4$ gel<br>$SiO_2$ with<br>HCl | 1  |
| Vit.                  | W., C.  | C.                 | Brittle                          |             |  | 2  |
| Vit.                  | Bright B.                                     | W.                 |                                  | Inf.        | E.S. $H_2O$                                    | 3  |
| Vit. res.             | W., Br., Y.,<br>R.,<br>tl.—stl.               | W., Y.,<br>Gr.     | Uneven                           | Inf.        | Gelatinous<br>$SiO_2$ with<br>HCl.             | 4  |
|                       |   |                    |                                  |             |  | 5  |
| Dull                  | Gr.   | Gr.                | Earthy                           |             |  | 6  |
|                       |   |                    |                                  |             |  | 7  |
|                       |   |                    |                                  |             |  | 8  |
| Submet                | Iron or<br>Br. Bl.                            | Dark Br.           | Rough                            | Inf.        | Ins.   | 9  |
|                       | Bl.   |                    |                                  |             |  | 10 |
| Vit.                  | All shades of<br>G.                           | C.                 | Conch.,<br>uneven                | Inf.        | Ins.   | 11 |
| Enamel-<br>like       | B. G., sky or<br>turquoise B.                 | W.                 | Conch.,<br>brittle or<br>sectile | Inf.        | s.acids  | 12 |
| Vit.                  | P. G., tr;<br>olive G.,<br>Br., tl or<br>stl. | C.                 | Conch.                           | Inf.        | Ins.   | 13 |
| Vit.                  | Apple G.                                      | G.                 | Splintery                        | Inf.        | s.HF and<br>KOH                                | 14 |
|                       |   |                    |                                  |             |  | 15 |
| Ad.                   | R., Gr., Br.                                  | Scarlet            | Subconch.,<br>uneven             | Volatilizes |  | 16 |
| Vlt., res. or<br>dull | Cinnamon or<br>Y.<br>Y. W.                    | W.<br>Citron<br>Y. | Flat conch.                      | Inf.        | Ins.   | 17 |
|                       |   |                    |                                  |             |  | 18 |
|                       |   |                    |                                  |             |  | 19 |
| Met.                  | Gr.   | Gr.                | $\infty O \infty$                | Inf.        | s. $HNO_3$                                     | 20 |
|                       |   |                    |                                  |             |  | 21 |
| Dull                  | Gr., W., Y.,<br>Br., R.                       |                    | Pasty                            | Inf.        | Ins.   | 22 |
|                       |   |                    |                                  |             |  | 23 |
| Dull                  | Bl.   | Bl., Br.           |                                  |             | s.HCl,<br>PbCl <sub>2</sub> seps<br>out        | 24 |
|                       |   |                    |                                  |             |  | 25 |
|                       |   |                    |                                  |             |  | 26 |
|                       |   |                    |                                  |             |  | 27 |
| Met.—py.              | R.Br., Y. Br.,<br>Y.                          | Y.                 | oP                               | Inf.        | s.HCl  | 28 |
| Submet.               | Bl.   | Bl.                | Conch.                           | Burns       |  | 29 |
| Dull                  | Br., Bl.                                      | Br.                | Conch.                           | Burns       |  | 30 |
|                       |   |                    |                                  |             |  | 31 |
|                       |   |                    |                                  |             |  | 32 |
|                       |   |                    |                                  |             |  | 33 |
|                       |   |                    |                                  |             |  | 34 |
| Met.                  | W. tinged R.                                  | Gr. Bl.            | Brittle                          | Fus.        | s.hot $HNO_3$                                  | 35 |
| Dull                  | W., G.  | W.                 | Granular                         | Fus.        | Ins.   | 36 |
| Vit.                  | W., Y. W., C.                                 | W.                 | $\infty P \infty$                | Fus.        | s.hot HCl.                                     | 37 |

| Name.                       | Composition.  | Cryst. System.                    | Specific Gravity.    | Hardness. |
|-----------------------------|---|-----------------------------------|----------------------|-----------|
| 1 Colophonite               | See Garnet, Iron-lime   | Am.                               | 3.44                 | 7         |
| 2 Columbite                 | (Fe,Mn) (Nb,Ta) <sub>2</sub> O <sub>6</sub>                               | IV.                               | 5.25—7.3             | 6         |
| 3 Connellite                | CuSO <sub>4</sub> .CuCl <sub>2</sub>                                      | III.                              | 2.9—3.2              | 2—3       |
| 4 Copaline (Highgate Resin) | A Bitumen.  |                                   |                      |           |
| 5 Copiapite                 | Fe <sub>4</sub> S <sub>2</sub> O <sub>18</sub> +12 H <sub>2</sub> O       | V.                                | 2.1                  | 2.5       |
| 6 Copper, Native            | Cu  | I.                                | 8.8                  | 2.5—3     |
| 7 — black                   | See Melaconite.   |                                   |                      |           |
| 8 — blue                    | See Covellite.  |                                   |                      |           |
| 9 — froth                   | Copper arsenate (43.9 % CuO)  | IV                                | 4.2                  | 2.5—3     |
| 10 — glance                 | See Redruthite.   |                                   |                      |           |
| 11 — grey                   | See Tetrahedrite.   |                                   |                      |           |
| 12 — mica                   | See Chalcophyllite  |                                   |                      |           |
| 13 — nickel                 | See Kupfernickel.   |                                   |                      |           |
| 14 — pyrites                | Cu <sub>2</sub> S.Fe <sub>2</sub> S <sub>2</sub>                          | II. sph.                          | 4.1—4.3              | 3.5—4     |
| 15 — red                    | See Cuprite.  |                                   |                      |           |
| 16 — silicate               | See Dioptase, Chrysocolla.  |                                   |                      |           |
| 17 — vitriol                | See Chalcanthite.   |                                   |                      |           |
| 18 Copperas                 | FeSO <sub>4</sub> .7 H <sub>2</sub> O                                     | V.                                | 1.83                 | 2         |
| 19 Coprolites               | Apatite of organic origin.  | (Supposed to be excrement of)     |                      |           |
| 20 Coquimbite               | Fe <sub>2</sub> S <sub>2</sub> O <sub>12</sub> .9 H <sub>2</sub> O        | IV.                               | 2—2.1                | 2—2.5     |
| 21 Cordierite               | See Iolite.   |                                   |                      |           |
| 22 Corundum                 | Al <sub>2</sub> O <sub>3</sub>  | III. rh.                          | 3.90—4.16            | 9         |
| 23 Cossyrite                | Amphibole, with Na <sub>2</sub> TiO <sub>3</sub>                          | VI.                               |                      |           |
| 24 Cotunnite                | PbCl <sub>2</sub> (74.5% Pb)  | IV.                               | (Acicular crystals.) |           |
| 25 Covellite                | CuS   | III. rh. h.                       | 4.59—4.6             | 1.5—2     |
| 26 Crocidolite              | (Fe,Na) <sub>2</sub> Si <sub>4</sub> O <sub>11</sub> .FeSiO <sub>3</sub>  | V.                                | 3.2                  | 4         |
| 27 Crocoite (crocoisite)    | PbO.CrO <sub>3</sub>  | V.                                | 5.9—6.1              | 2.5—3     |
| 28 Cromfordite              | PbCl <sub>2</sub> .PbCO <sub>3</sub>                                      |                                   | 6—6.31               | 2.75—3    |
| 29 Cronstedtite             | Chlorite, containing Mn   | III.                              | 3.35                 | 3         |
| 30 Crookesite               | CuSe with 17.25% Th and a little Ag                                       | I.                                |                      |           |
| 31 Cryolite                 | 3 NaF.AlF <sub>3</sub>  | V.                                | 2.9—3                | 2.5—3     |
| 32 Cuprite                  | Cu <sub>2</sub> O   | I.                                | 5.8—6.15             | 3.5—4     |
| 33 Cyanite                  | See Kyanite.  |                                   |                      |           |
| 34 Cyanosite                | See Chalcanthite.   |                                   |                      |           |
| 35 Danaite                  | Mispickel with 6.5% Co  | Other properties as for mispickel |                      |           |
| 36 Danalite                 | 2 (Mg,Fe)O.SiO <sub>2</sub> with Zn,Be,Fe & Mn                            | I.                                | 3.42                 | 5.5       |
| 37 Danburite                | CaO.B <sub>2</sub> O <sub>3</sub> .2 SiO <sub>2</sub>                     | IV.                               | 2.95                 | 7         |
| 38 Datolite                 | 2 CaO.B <sub>2</sub> O <sub>3</sub> .2 SiO <sub>2</sub> .H <sub>2</sub> O | V                                 | 2.9—3                | 3—5.5     |

| Lustre.       | Colour                     | Streak.       | Fracture                      | Fusibility. | Solubility.                              |    |
|---------------|----------------------------|---------------|-------------------------------|-------------|--|----|
| Res.          | Dark R. Br.                | P             | Granular,<br>coarse           |             |  | 1  |
| Met. ad.      | Br., Gr. Bl.               | Bl., Br.<br>R | $\infty P \infty$             | Inf.        | Ins.                                     | 2  |
| Vit. ad.      | Fine Bl                    | W             | Conch                         |             | s. $H_2O$                                | 3  |
| Wax           | Pale Y or Br.              | Y             |                               | Burns       |  | 4  |
| Py.           | Y., Y. G.                  | Y.            | $\infty P \infty$             | Inf.        | s. $H_2O$                                | 5  |
| Met           | Copper R.                  | Met. R        |                               | Fus. 2—3    | s. $HNO_3$                               | 6  |
|               |                            |               |                               |             |  | 7  |
|               |                            |               |                               |             |  | 8  |
| Dull          | Apple G                    | G.            |                               |             |  | 9  |
|               |                            |               |                               |             |  | 10 |
|               |                            |               |                               |             |  | 11 |
|               |                            |               |                               |             |  | 12 |
|               |                            |               |                               |             |  | 13 |
| Met.          | Brass Y                    | G. Bl.        | Conch.,<br>uneven             | Fus.        | s. $HNO_3$ with<br>sepn. of S.           | 14 |
|               |                            |               |                               |             |  | 15 |
|               |                            |               |                               |             |  | 16 |
|               |                            |               |                               |             |  | 17 |
| Vit. glazy    | G., Y. Br., W.             | C.            | C'ch., brittle                | Fus.        | s. $H_2O$                                | 18 |
| certain sauri | ans, &c.)                  |               |                               |             |  | 19 |
| Vit.          | W., Y., Br., B.            | W             | Brittle                       | Inf.        | s. $H_2O$                                | 20 |
|               |                            |               |                               |             |  | 21 |
| Vit. or dull  | W. Gr., Y.,<br>R., Br., B. | W.            | Conch.                        | Inf.        | Ins.                                     | 22 |
|               |                            |               |                               |             |  | 23 |
|               |                            |               |                               |             |  | 24 |
| Wax, dull     | W.<br>Dull B. Bl.          | Gr., Bl.      | oR                            | E. fus.     | s. $HNO_3$ with<br>sepn. of S.           | 25 |
| Sy. Asbesti-  | Leek G. Y.,                | B. Gr.        | Fibrous                       | E. fus.     | Ins.                                     | 26 |
| form          | Br., B.                    |               |                               |             |  |    |
| Ad.—vit.      | Hyacinth R.,<br>tl.        | Orange        | $\infty P$                    | E. fus.     | s. hot HCl.<br>with Sepn.<br>of $PbCl_2$ | 27 |
| Ad.           | W. Gr., Y.<br>tr. tl.      | W.            | Conch.                        |             | s. $HNO_3$ with<br>loss of $CO_2$        | 28 |
| Vit.          | Bl.                        |               | oP                            |             |  | 29 |
|               | Bl., Gr.                   | Gr.           |                               |             |  | 30 |
| Vit.          | C., W. Gr.                 | C.            | $\infty P, oP, P \infty$      | 1           | s. $H_2SO_4$                             | 31 |
| Ad. sub.      | R. (cochineal)             | Br R.         | Conch.,<br>uneven,<br>brittle | Fus.        | s. acids                                 | 32 |
| met.          |                            |               |                               |             |  | 33 |
|               |                            |               |                               |             |  | 34 |
|               |                            |               |                               |             |  | 35 |
| Vit. res.     | Flesh R.—Gr.               | Gr. P.        |                               | Inf.        | Gelatinous<br>$SiO_2$ with<br>HCl.       | 36 |
| Vit. oily     | Y., W.                     | Y.            | Uneven                        | 3           | Gelatinous<br>$SiO_2$ with<br>HCl.       | 37 |
| Vit.          | C., W., Gr. G.,<br>Y., R.  | C. W.         | Conch.,<br>uneven             | 2           | Gelatinous<br>$SiO_2$ with<br>HCl.       | 38 |

|    | Name.             | Composition.  | Cryst. System. | Specific Gravity.  | Hardness |
|----|-------------------|---|----------------|--------------------|----------|
| 1  | Dawsonite         | $\text{Al}_2(\text{CO}_3)_3 \cdot \text{Na}_2\text{CO}_3 \cdot n\text{H}_2\text{O}$   |                |                    |          |
| 2  | Delessite         | $4 (\text{Mg}, \text{Fe})\text{O} \cdot 2 (\text{Al}_2, \text{Fe}_2)\text{O}_3 \cdot 4 \text{SiO}_2 \cdot 5 \text{H}_2\text{O}$ ,<br>rich in iron | Microcryst     | 2.7—2.9            | 2—2.5    |
| 3  | Derbyshire Spar   | See Fluor Spar.   |                |                    |          |
| 4  | Decloizite        | $3 \text{PbO} \cdot \text{V}_2\text{O}_5 \cdot \text{Zn}(\text{OH})_2$  | IV.            | 5.8—6.25           | 3.5      |
| 5  | Desmine           | $(\text{Ca}, \text{Na})_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6 \text{SiO}_2 + 6 \text{H}_2\text{O}$  | V.             | 2.1—2.2            | 3.5—4    |
| 6  | Deweylite         | $3 \text{MgO} \cdot \text{H}_2\text{O} \cdot 2 \text{SiO}_2 + 20\% \text{H}_2\text{O}$  | Am.            | 1.9—2.25           | 2—3.5    |
| 7  | Diallage          | $(\text{Mg}, \text{Fe})\text{O} \cdot \text{CaO} \cdot 2 \text{SiO}_2$<br>with some $\text{Al}_2\text{O}_3$                                       | V.             | 3.2—3.3            | 4        |
| 8  | Diallogite        | See Rhodochrosite.  |                |                    |          |
| 9  | Diamond           | C.  | I.             | 3.52               | 10       |
| 10 | Diaphorite        | $5 (\text{Pb}, \text{Ag}_2)\text{S} \cdot 2 \text{Sb}_2\text{S}_3$  | IV.            | As for Freibergite |          |
| 11 | Diaspore          | $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$  | IV.            | 3.5                | 6.5—7    |
| 12 | Dichroite         | See Iolite.   |                |                    |          |
| 13 | Dickinsonite      | $3 (\text{Mn}, \text{Fe})\text{O} \cdot \text{P}_2\text{O}_5 + \text{CaF}_2$  | IV.            | 3.4—3.8            | 5—5.5    |
| 14 | Dihydrite         | See Pseudomalachite.  |                |                    |          |
| 15 | Diopside          | $\text{MgO} \cdot \text{CaO} \cdot 2 \text{SiO}_2$  | V.             | 3.3                | 5—6      |
| 16 | Diopside          | $\text{CuO} \cdot \text{SiO}_2 + \text{H}_2\text{O}$  | III.rh.t.      | 3.2—3.35           | 5        |
| 17 | Diorite           | Rock. Hornblende<br>and Felspar   |                |                    |          |
| 18 | Diphanite         | See Margarite.  |                |                    |          |
| 19 | Disthene          | See Kyanite.  |                |                    |          |
| 20 | Dog-tooth spar    | See Calcite   | III.rh.h.      |                    |          |
| 21 | Dolerophanite     | $\text{CuSO}_4 \cdot \text{CuO}$  | V.             | 3.5—3.7            |          |
| 22 | Dolomite          | $\text{CaCO}_3 \cdot \text{MgCO}_3$   | III.rh.        | 2.8—2.9            | 3.5—4    |
| 23 | Domeykite         | $\text{Cu}_3\text{As}_2$  | I.             | 7—7.5              | 3—3.5    |
| 24 | Dufrenoyite       | $2 \text{PbS} \cdot \text{As}_2\text{S}_3$  | IV.            | 5.5—5.7            | 3        |
| 25 | Dumortierite      | $4 \text{Al}_2\text{O}_3 \cdot 3 \text{SiO}_2$  | IV.            | 3.3—3.4            | 7        |
| 26 | Durangite         | $2 \text{NaF} \cdot \text{Al}_2\text{O}_3 \cdot \text{As}_2\text{O}_5$  | V.             | 3.9—4.1            | 5        |
| 27 | Dysanallyte       | $(\text{Ca}, \text{Ce}, \text{Fe})\text{O} \cdot \text{Nb}_2\text{O}_5$   | I.             |                    |          |
| 28 | Dyscrasite        | $\text{Ag}_3\text{Sb}$  | IV.            | 9.4—9.8            | 3—3.5    |
| 29 | Earthy Cobalt     | Wad(q.v.) with 0—40%<br>$\text{CoO} \cdot \text{CoS}$ , $\text{CuO}$ ,<br>$\text{Fe}_2\text{O}_3$ , $\text{NiO}$                                  | Am.            |                    |          |
| 30 | Edingtonite       | $\text{BaO} \cdot \text{Al}_2\text{O}_3 \cdot 3 \text{SiO}_2 \cdot 3 \text{H}_2\text{O}$  | I.sph.h.       | 2.7                | 4—4.5    |
| 31 | Eggonite          | $\text{CdO} \cdot \text{SiO}_2$   | IV.            |                    | 4—5      |
| 32 | Ehlite            | See Pseudomalachite.  |                |                    |          |
| 33 | Elæolite          | See Nepheline.  |                |                    |          |
| 34 | Elastic Bitumen   | See Bitumen, elastic  |                |                    |          |
| 35 | Elaterite         | See Bitumen, elastic.   |                |                    |          |
| 36 | Electric Calamine | See Hemimorphite.   |                |                    |          |
| 37 | Electrum          | $\text{Au}_m\text{Ag}_n$ ( $\text{Ag} > 20\%$ )   | I.             | 13—16              | 2.5—3    |

| Lustre.           | Colour.                     | Streak.            | Fracture.                     | Fusibility.           | Solubility   |    |
|-------------------|-----------------------------|--------------------|-------------------------------|-----------------------|--|----|
|                   | C. W.                       |                    |                               |                       |  | 1  |
| Vit.              | G., Bl. G.                  | Gr. G.             | Fibrous                       | d.fus.                | Flocculent<br>SiO <sub>2</sub> with<br>HCl.                      | 2  |
|                   |                             |                    |                               |                       |  | 3  |
|                   | Bl., Br., Olive<br>G.       | Br.                |                               |                       |  | 4  |
| Vit.              | C., W., Y                   | W.                 | ∞ P ∞                         | Fus.                  | Powdery<br>SiO <sub>2</sub> with<br>HCl.                         | 5  |
| Res.              | W. tinge Y.,<br>Br., G., R. | W.                 | Very brittle                  |                       |  | 6  |
| Py met.           | Gr., G., Br.,<br>tr. tl.    | W., Gr.            | Brittle                       | 5                     | Ins.   | 7  |
|                   |                             |                    |                               |                       |  | 8  |
| Ad.               | C., P., Y., B.,<br>Bl.      |                    | Conch.                        | Inf.                  | Ins.   | 9  |
|                   |                             |                    |                               |                       |  | 10 |
| Sy. py.           | C., Gr., Y.                 |                    | ∞ P ∞                         | Inf.                  | s.H <sub>2</sub> SO <sub>4</sub> after<br>heating to<br>red heat | 11 |
|                   |                             |                    |                               |                       |  | 12 |
| Res.              | Oil G., olive<br>G.         | Gr. G.             |                               | E. fus.               | s.HCl.   | 13 |
|                   |                             |                    |                               |                       |  | 14 |
| Vit.              | C., Gr., G.                 | C.                 | ∞ P 87°                       | 3—4                   | Ins.   | 15 |
| Vit.              | Emerald G.,<br>tr. stl.     | G.                 | Conch.,<br>uneven,<br>brittle | Inf.                  | Gelatinous<br>SiO <sub>2</sub> with<br>HCl.                      | 16 |
|                   |                             |                    |                               |                       |  | 17 |
|                   |                             |                    |                               |                       |  | 18 |
|                   |                             |                    |                               |                       |  | 19 |
|                   |                             |                    |                               |                       |  | 20 |
| Vit.              | B.                          | Br.                | Brittle                       |                       |  | 21 |
| Vit. py.,<br>dull | W., Y., Br.,<br>G.          | W. Gr.             | Conch. or<br>uneven           | Inf.                  | s.warm acids   | 22 |
| Met.              | W.—pinch-<br>beck Br.       | W.                 | Conch.                        | Fus.                  | s.HNO <sub>3</sub>   | 23 |
| Met.              | Gr., Gr. Bl.                | R. Br.             | oP                            | E. fus.               |  | 24 |
|                   | B., Gr. B.                  |                    |                               | Inf.                  |  | 25 |
| Vit.              | R., Y.                      | Y.                 | ∞ P                           | E. fus.               | s.H <sub>2</sub> SO <sub>4</sub>                                 | 26 |
|                   | Gr. Bl.                     |                    |                               |                       |  | 27 |
| Met.              | Tin W.                      | W met.             | oP, P ∞                       | 3.5 Sb<br>volatilises | s.HNO <sub>3</sub>   | 28 |
| Dull              | Bl., B. Bl.                 | Bl. res.           | Earthy                        | Int.                  | s.HCl.   | 29 |
|                   |                             |                    |                               |                       |  | 30 |
| Vit.              | Gr. W., P.                  |                    | ∞ P                           | d. fus.               | Gelatinous<br>SiO <sub>2</sub> with<br>HCl.                      | 31 |
| Sub. ad.          | Tl., Gr. Br.                |                    | oP, P ∞                       | Inf.                  |  | 32 |
|                   |                             |                    |                               |                       |  | 33 |
|                   |                             |                    |                               |                       |  | 34 |
|                   |                             |                    |                               |                       |  | 35 |
|                   |                             |                    |                               |                       |  | 36 |
| Met.              | Y., W.                      | Y., W.,<br>shining | Tough                         | Fus.                  | s.HNO <sub>3</sub> +<br>HCl.                                     | 37 |

| Name.           | Composition.   | Cryst. System. | Specific Gravity. | Hardness |
|-----------------|--|----------------|-------------------|----------|
| 1 Eleonorite    | $3 \text{ Fe}_2\text{O}_3 \cdot 2 \text{ P}_2\text{O}_5 \cdot 8 \text{ H}_2\text{O}$   | V.             |                   | 3—4      |
| 2 Eliasite      | $\text{UO}_2 \cdot \text{U}_2\text{O}_3 \cdot x \text{ H}_2\text{O}$   |                | 9.2—9.3           | 5.5      |
| 3 Elpasolite    | $3 \text{ K.F. AlF}_3$ (Cryolite)  | with K ins     | stead of Na)      |          |
| 4 Elpidite      | $\text{Na}_2\text{O} \cdot \text{ZrO}_2 \cdot 6 \text{ SiO}_2 \cdot 3 \text{ H}_2\text{O}$   |                |                   |          |
| 5 Embolite      | $\text{Ag}(\text{Cl}, \text{Br})$  | I.             | 5.79              | 1.5      |
| 6 Emerald       | See Beryl (contains Cr.)   |                |                   |          |
| 7 — Brazilian   | Tourmaline (q.v.)  |                |                   |          |
| 8 — Oriental    | See Corundum.  |                |                   |          |
| 9 — Copper      | See Dioptase.  |                |                   |          |
| 10 — Nickel     | $\text{NiCO}_3 \cdot 6 \text{ H}_2\text{O}$  | Am.            | 2.5—2.6           | 3—3.25   |
| 11 Emery        | See Corundum.  |                |                   | 8.5—9    |
| 12 Emeryllite   | See Margarite.   |                |                   |          |
| 13 Emmonsite    | $\text{FeTeO}_3$   | V.             | 5                 | 2        |
| 14 Emplectite   | $\text{Cu}_2\text{S} \cdot \text{Bi}_2\text{S}_3$  | IV.            | 6.23—8.52         | 2.5      |
| 15 Enargite     | $6 \text{ CuS} \cdot \text{As}_2\text{S}_3$  | IV.            | 4.3—4.5           | 3        |
| 16 Endellionite | See Bournonite.  |                |                   |          |
| 17 Enstatite    | $\text{MgO} \cdot \text{SiO}_2$ or $(\text{MgO}, \text{FeO})\text{SiO}_2$  | IV.            | 3.1—3.3           | 5.5      |
| 18 Eosphorite   | $(\text{Fe}, \text{Al}, \text{Mn})_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 5 \text{ H}_2\text{O}$ . Mn essential, Fe low percentage     | IV.            | 3.1—3.5           | 5.5—6    |
| 19 Epidote      | $4 \text{ CaO} \cdot 3(\text{Al}, \text{Fe})_2\text{O}_3 \cdot 6 \text{ SiO}_2 \cdot \text{H}_2\text{O}$                                     | V.             | 3.2—3.5           | 6—7      |
| 20 Epistilbite  | $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 6 \text{ SiO}_2 \cdot 5 \text{ H}_2\text{O}$   | V.             | 2.24—2.36         | 3.5—4    |
| 21 Epsom Salt   | $\text{MgSO}_4 \cdot 7 \text{ H}_2\text{O}$  | IV.            |                   |          |
| 22 Erinite      | $2 \text{ CuO} \cdot \text{As}_2\text{O}_3 \cdot 4 \text{ H}_2\text{O}$  | Deposit        | 4.04              | 4.5—5    |
| 23 Erubescite   | See Bornite.   |                |                   |          |
| 24 Erythrine    | $3 \text{ CoO} \cdot \text{As}_2\text{O}_3 \cdot 8 \text{ H}_2\text{O}$  | V.             | 2.95              | 1.5—2.5  |
| 25 Essonite     | See Garnet, Lime-alum  | ina.           |                   |          |
| 26 Ettringite   | $\text{CaSO}_4 \cdot \text{Al}_2(\text{SO}_4)_3$   | III.           |                   | 3—3.5    |
| 27 Eucairite    | $\text{Ag}_2\text{Se} \cdot \text{Cu}_2\text{Se}$  |                | 7—9               | 1        |
| 28 Euchroite    | $\text{CuO} (48\%) \cdot \text{As}_2\text{O}_3 (33\%)$   | IV.            | 3.39              | 3.75     |
| 29 Eudeiolite   | $(\text{Ca}, \text{Ce}, \text{Fe}, \text{Hg}, \text{Na})\text{O} \cdot (\text{Nb}, \text{Ti}, \text{Th})\text{O}_2 \cdot \text{H}_2\text{O}$ | I.             | 3.44              | 4        |
| 30 Eudialite    | $\text{NaCl} \cdot 6 \text{ Na}_2\text{O} \cdot 6(\text{Fe}, \text{Ca})\text{O} \cdot 20(\text{Si}, \text{Zr})\text{O}_2$                    | III.rh.h.      | 2.8—2.9           | 5—5.5    |
| 31 Euclase      | $2 \text{ BeO} \cdot \text{Al}_2\text{O}_3 \cdot 2 \text{ SiO}_2 \cdot \text{H}_2\text{O}$   | V.             | 3.1               | 7.5      |
| 32 Eucrasite    | Altered Thorite  | Am.            | 4.39              | 4.5—5    |
| 33 Enlytine     | $2 \text{ Bi}_2\text{O}_3 \cdot 3 \text{ SiO}_2$   | I.tetr.h.      | 6.1               | 4.5      |

| Lustre.                | Colour.   | Streak.                                     | Fracture.                             | Fusibility.        | Solubility.  |                       |
|------------------------|---|---|---------------------------------------|--------------------|--|-----------------------|
| Vit. py.<br>Res.       | R., R. Br.<br>R. Br., BL                        | Y   | $\infty P \infty$                     | E. fus.            | E.s.HCl.   | 1<br>2<br>3<br>4      |
| Ad.                    | G.<br>Bright G.<br>Tr. G.<br>Tr. G.             | Y. G.                                       | Conch.                                | E. fus.            | d.s.HCl.   | 5<br>6<br>7<br>8<br>9 |
| Vit.                   | Emerald G.,<br>tr. tl.<br>Gr. BL                | Pale G.                                     | Brittle                               | Inf.               | s.dil.HCl.   | 10<br>11<br>12<br>13  |
| Met.<br>Met.           | Y. G.<br>Gr. W.<br>Gr. BL                       | Bl.<br>Bl.                                  | $\infty P \infty$<br>$\infty P$       | E. fus.<br>E. fus. | s.HNO <sub>3</sub><br>s.HNO <sub>3</sub> with<br>sepn. of S.       | 14<br>15<br>16<br>17  |
| Vit. py.<br>Rather wax | Gr., G., Br.,<br>Y., C.,<br>stl.—op.<br>Rose R. | W Gr.<br>P                                  | $\infty P, \infty P \infty$           | 6                  | Ins.   | 18                    |
| Vit.                   | G., Y G.,<br>Br G., BLG.                        | Gr.   | $\infty P, \infty P \infty$           | 3·5                | After heating<br>to red heat<br>gel. SiO <sub>2</sub><br>HCl.      | 19                    |
| Py., vit.              | C., W.,<br>W. B.                                |   | $\infty P \infty$                     | Fus.               | Decomp<br>hot HCl<br>with forma.<br>of powdery<br>SiO <sub>2</sub> | 20                    |
| Vit.—earthy<br>Dull    | W.<br>Emerald G.                                | W<br>G.                                     |                                       | Gives off<br>Fus.  | water s. H <sub>2</sub> O  | 21<br>22<br>23        |
| Py. ad. vit.,<br>dull  | Peach R.,<br>crimson,<br>G. or Gr               | As colour<br>but paler,<br>Laven-<br>der B. | Earthy                                | Fus.               | s.HCl.   | 24                    |
| Vit.<br>Met.           | W<br>Silver W.—<br>lead Gr.                     | W<br>Gr.                                    | Powdery<br>Tough                      |                    |  | 25<br>26<br>27        |
| Wax —dull<br>Vit       | Bright G.<br>Bl Br.                             | G.<br>?                                     | Brittle<br>Conch<br>brittle           | Fus.               | s.HNO <sub>3</sub>   | 28<br>29              |
| Vit.                   | R., P., Br                                      |   | $\infty R$                            | E fus.             | Gelatinous<br>SiO <sub>2</sub> with<br>HCl.                        | 30                    |
| Vit.<br>Waxy           | G., W, C., B.,<br>tr<br>Bl, Br                  | Br  | $\infty P \infty$<br>Uneven,<br>conch | 3·5<br>d fus       | Ins.<br>s H <sub>2</sub> SO <sub>4</sub>                           | 31<br>32              |
| Ad.                    | Br., Y., Gr                                     | W. G.<br>Gr                                 | Conch                                 | E. fus.            | Gelatinous<br>SiO <sub>2</sub> with<br>HCl.                        | 33                    |



| Name. |                         | Composition.  | Cryst. System. | Specific Gravity. | Hardness. |
|-------|-------------------------|---|----------------|-------------------|-----------|
| 1     | Euphyllite              | $\text{CaO.K}_2\text{O.3 Na}_2\text{O.}$<br>$14 \text{ Al}_2\text{O}_3.23 \text{ SiO}_2.$<br>$9 \text{ H}_2\text{O}$  | Schistose      | 2.5—3             | 2—2.5     |
| 2     | Eusynchite              | $(\text{Pb,Cu})\text{O.V}_2\text{O}_5$  |                |                   |           |
| 3     | Euxenite                | $(\text{Y,Ce,Er})_2\text{Ti}_5\text{O}_{15},$<br>$(\text{Y,Er,Ce})_2\text{Nb}_6\text{O}_{18}.$<br>$\text{Fe}(\text{UO})\text{Ti}_5\text{O}_{15}.$<br>$\text{Fe}(\text{UO})\text{Nb}_6\text{O}_{18},$<br>containing Ge | IV.            | 4.6—5             | 6.5       |
| 4     | Fahlerz                 | See Tetrahedrite.   |                |                   |           |
| 5     | Fahlunite               | $2 \text{ FeO.SiO}_2.\text{Al}_2\text{O}_3.$<br>$2 \text{ SiO}_2.\text{H}_2\text{O}$  | III.           | 2.7               | 1.5—2     |
| 6     | Fairfieldite            | $(\text{Mg,Ca})_3(\text{PO}_4)_2.x \text{ H}_2\text{O}$   | VI.            |                   | 3.5       |
| 7     | Faujasite               | $(\text{Na}_3\text{Ca})\text{O.Al}_2\text{O}_3.$<br>$5 \text{ SiO}_2.10 \text{ H}_2\text{O}$  | I.             | 1.9               | 5—5.5     |
| 8     | Fayalite                | $2 \text{ FeO.SiO}_2$   | IV.            | 3.9—4.1           | 6         |
| 9     | Feather ore             | See Jamesonite.   |                |                   |           |
| 10    | Felspar, Potash         | $\text{K}_2\text{O.Al}_2\text{O}_3.6 \text{ SiO}_2$<br>(See also Microcline)  | V or VI.       | 2.55—2.58         | 6         |
| 11    | —, Soda                 | See Albite.   |                |                   |           |
| 12    | Felsite                 | Orthoclase. (Has the  | texture of     | flint or jas      | per.)     |
| 13    | Ferberite               | $\text{FeWO}_4$   | V.             | 6.7—6.8           | 4—4.5     |
| 14    | Fergusonite             | $\text{Y}(\text{Nb,Ta})\text{O}_4$  | II. pyr. h.    | 5.8—5.9           | 5.5—6     |
| 15    | Ferrotellurite          | $\text{FeTeO}_4$  |                |                   |           |
| 16    | Fibrolite               | $\text{Al}_2\text{O}_3.\text{SiO}_2$  | IV.            | 3.2—3.3           | 6—7       |
| 17    | Fichtelite              | $\text{C}_{12}\text{H}_{22}$  | V.             |                   |           |
| 18    | Fiorite                 | $\text{SiO}_2$  | Globular       |                   |           |
| 19    | Fischerite              | $2 \text{ Al}_2\text{O}_3.\text{P}_2\text{O}_5.+8 \text{ H}_2\text{O}$  | IV.            | 2.5               | 5         |
| 20    | Flint                   | $\text{SiO}_2$ , compact  | III.           | 2.6—2.64          | 7         |
| 21    | Float Stone             | Porous opal   |                |                   |           |
| 22    | Flos ferri              | $\text{CaCO}_3$ with iron (Coral  | loidal).       |                   |           |
| 23    | Fluellite               | $\text{AlFe}_3.\text{H}_2\text{O}$  | IV.            | 2.17              |           |
| 24    | Fluocerite              | $(\text{Ce,L a,D i})_2\text{OF}_4;$<br>Cerium ore 82%   | III.           | 5.7—5.9           | 4         |
| 25    | Fluorite                | $\text{CaF}_2$  | I.             | 3—3.25            | 4         |
| 26    | Fluor Spar              | See Fluorite.   |                |                   |           |
| 27    | Foliated Tellurium      | See Nagyagite.  |                |                   |           |
| 28    | Fontainebleau Limestone | $\text{CaCO}_3$ with up to.<br>85% $\text{SiO}_2$   | III.rh.        |                   |           |
| 29    | Forsterite              | $2 \text{ MgO.SiO}_2$   | IV.            | 3.2—3.3           | 7         |
| 30    | Fowlerite               | $(\text{Mn,Fe,Ca,Zn,Mg})\text{O.}$<br>$\text{SiO}_2$  | V.             | 3.3—3.6           | 4—5       |
| 31    | Franklinite             | $(\text{Fe,Zn,Mn})\text{O.Fe}_2\text{O}_3$  | I.             | 5—5.1             | 6—6.5     |
| 32    | Freibergite             | Argentiferous Tetrahe   | drite (q.v.)   |                   |           |
| 33    | Freislebenite           | $5(\text{Pb,Ag}_2)\text{S.2 Sb}_2\text{S}_3$  | V.             | 6.2—6.4           | 2—2.5     |
| 34    | French Chalk            | Talc' (q.v.).   |                |                   |           |
| 35    | Freyalite               | $\text{ThSiO}_4$  | Am.            | 4—4.2             |           |
| 36    | Friedelite              | $\text{Mn}_3\text{SiO}_4$   |                |                   |           |
| 37    | Fuchsite                | Muscovite contg. Cr.  | V.             | 2.6—2.8           |           |
| 38    | Fuller's Earth          | $2 \text{ Al}_2\text{O}_3.3 \text{ SiO}_2+\text{aq}$  | Am.            |                   | 1—1.5     |



| Lustre.            | Colour.                   | Streak.       | Fracture.            | Fusibility. | Solability.   |    |
|--------------------|---------------------------|---------------|----------------------|-------------|---|----|
| Py.                | C., W.                    | W.            | Brittle              | Fus.        |   | 1  |
|                    | Olive G.;<br>Bl.G.        | G.            |                      |             |   | 2  |
| Greasy             | Br.Bl.                    | R.Br.         | Conch.               | Inf.        | Ins.  | 3  |
|                    |                           |               |                      |             |   | 4  |
| Py.                | Gr.G.—Bl.                 | G.            | Brittle              | Fus.        | Ins.  | 5  |
|                    | W., Y.                    |               |                      | D. fus.     |   | 6  |
| Vit.—ad.           | C., W.                    |               | Am.                  | E. fus.     | Gelatinous<br>SiO <sub>2</sub> with HCl               | 7  |
| Fatty              | G.Bl.—Bl.                 | Br.           |                      | E. fus.     | Gelatinous<br>SiO <sub>2</sub> with HCl               | 8  |
|                    |                           |               |                      |             |   | 9  |
| Vit.               | W., P., Gr.,<br>G., B.    | W.Gr.         | Conch.<br>splintery  | 5           | Ins.  | 10 |
|                    |                           |               |                      | 5           | Ins.  | 11 |
| Vit.               | Bl.                       | Bl.Br.        |                      |             |   | 12 |
| Met. fatty         | Bl., Bl.Br.               | Br.           | Incomplete<br>conch. | Inf.        |   | 13 |
|                    |                           |               |                      |             |   | 14 |
| Vit.               | Y., G.                    | W.            |                      |             |   | 15 |
| Vit.—py.           | Hair Br.—Gr.              | Gr.Br.        | Easy                 | Inf.        |   | 16 |
| Py.                | W.                        |               |                      | 46°         | s.(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> O     | 17 |
| Py.                | Py.W.                     | W.            |                      |             |   | 18 |
| Vit.               | G.                        | G.W.          |                      |             | s.H <sub>2</sub> SO <sub>4</sub>                      | 19 |
|                    | Smoky Gr.,<br>Br., Bl.    |               | Splintery            | Inf.        |   | 20 |
|                    |                           |               |                      |             |   | 21 |
|                    |                           |               |                      |             |   | 22 |
| Wax                | W.<br>P., G.              | ?             | Uneven               |             |   | 23 |
|                    |                           |               |                      |             |   | 24 |
| Vit.<br>glimmering | C., W., G., Y.,<br>purple | W.            | Conch.<br>uneven     | E. fus.     | s.H <sub>2</sub> SO                                   | 25 |
|                    |                           |               |                      |             |   | 26 |
|                    |                           |               |                      |             |   | 27 |
|                    |                           |               |                      |             |   | 28 |
| Vit.               | C., W., Y.                | ?             | ∞ P ∞                | Inf.        | Gelatinous<br>SiO <sub>2</sub> with HCl               | 29 |
| Vit.               | C., P., Gr., Y.           |               |                      | 3           |   | 30 |
| Met.               | Bl.                       | Br.           | Conch.<br>uneven     | Inf.        | s.hot HCl   | 31 |
|                    |                           |               |                      |             |   | 32 |
| Met.               | Bl.Gr.                    | Gr.           | Uneven               | E. fus.     | s.HNO <sub>3</sub> with<br>sepn. of PbSO <sub>4</sub> | 33 |
| Py.                | Milk W.<br>Br.            | Y.Gr.         |                      | Inf.        | s.HCl   | 34 |
| Vit.—res.          | Rose R.                   | P.            |                      |             |   | 35 |
|                    | G.                        |               | oP                   |             |   | 36 |
| Earthy             | G.Br., G.Gr.              | W.<br>shining | Earthy               | Fus.        |   | 37 |
|                    |                           |               |                      |             |   | 38 |

| Name.                  | Composition.   | Cryst. System. | Specific Gravity. | Hardness. |
|------------------------|--|----------------|-------------------|-----------|
| 1 Gadolinite           | $\text{FeO} \cdot 2 \text{SiO}_2 \cdot 2 \text{BeO} \cdot (\text{Y}, \text{Ce}, \text{La}, \text{Di})_2 \text{O}_3$                          | V.             | 4.2—4.35          | 6.5—7     |
| 2 Gahnite              | $(\text{Zn}, \text{Fe}) \text{O} \cdot \text{Al}_2 \text{O}_3$   | I.             | 4—4.6             | 7.5—8     |
| 3 Galena               | PbS  | I.             | 7.2—7.7           | 2.5—2.8   |
| 4 Galmei               | See Hemimorphite.  |                |                   |           |
| 5 Ganomatite           | $\text{Fe}_2 \text{O}_3 \cdot \text{As}_2 \text{O}_3 \cdot \text{Sb}_2 \text{O}_3 \cdot x \text{H}_2 \text{O}$                               | Am.            | 2—2.3             | Soft      |
| 6 Garnet, Lime-alumina | $6 \text{CaO} \cdot 3 \text{SiO}_2 + 2 \text{Al}_2 \text{O}_3 \cdot 3 \text{SiO}_2$  | I.             | 3.4—3.7           | 6.5—7     |
| 7 —, Magnesia-alumina  | $6 \text{MgO} \cdot 3 \text{SiO}_2 + 2 \text{Al}_2 \text{O}_3 \cdot 3 \text{SiO}_2$  | I.             | 3.69—3.8          | 7.5       |
| 8 —, Iron-alumina      | See Almandine.   | I.             |                   |           |
| 9 —, Manganese-alumina | $6 \text{MnO} \cdot 3 \text{SiO}_2 + 2 \text{Al}_2 \text{O}_3 \cdot 3 \text{SiO}_2$  | I.             | 3.7—4.4           | 7—7.5     |
| 10 —, Iron-lime        | $6 \text{CaO} \cdot 3 \text{SiO}_2 + 2 \text{Fe}_2 \text{O}_3 \cdot 3 \text{SiO}_2$  | I.             | 3.44              | 7+        |
| 11 —, Lime-chrome      | $6 \text{CaO} \cdot 3 \text{SiO}_2 + 2 \text{Cr}_2 \text{O}_3 \cdot 3 \text{SiO}_2$  | I.             | 3.4               | 7.5       |
| 12 Garnierite          | $(\text{Ni}, \text{Mg}) \text{O} \cdot \text{SiO}_2 + x \text{H}_2 \text{O}$   | Am.            | 2.3—2.8           | 2.5       |
| 13 Gaylussite          | $\text{Na}_2 \text{CO}_3 \cdot \text{CaCO}_3 \cdot 5 \text{H}_2 \text{O}$  | V.             | 1.9               | 2.5       |
| 14 Gehlenite           | $3 \text{CaO} \cdot \text{Al}_2 \text{O}_3 \cdot 2 \text{SiO}_2$   | II.            | 2.9—3             | 5.5—6     |
| 15 Genthite            | $(\text{Ni}, \text{Mg}) \text{O} \cdot \text{SiO}_2 \cdot x \text{H}_2 \text{O}$   | Am.            | 2.3—2.5           | 2.5       |
| 16 Geokronite          | $5 \text{PbS} \cdot \text{Sb}_2 \text{S}_3$  | IV.            | 6.4—6.5           | 2—2.5     |
| 17 Gerhardtite         | $\text{Cu}(\text{NO}_3)_2$   | IV.            | 3.2—3.7           | 3.5—4     |
| 18 Gersdorffite        | $\text{NiS}_2 + \text{NiAs}_2$   |                | 5.6—5.9           | 5.5       |
| 19 Gibbsite            | See Hydrargillite.   |                |                   |           |
| 20 Gismondine          | $\text{CaO} \cdot \text{Al}_2 \text{O}_3 \cdot 4 \text{SiO}_2 \cdot 4 \text{H}_2 \text{O}$   | V.             | 2.4               | 5—5.5     |
| 21 Glassy Felspar      | See Sanidine.  |                |                   |           |
| 22 Glauberite          | $\text{CaSO}_4 \cdot \text{Na}_2 \text{SO}_4$  | V.             | 2.7—2.8           | 2.5—3.    |
| 23 Glauber salt        | $\text{Na}_2 \text{SO}_4 \cdot 10 \text{H}_2 \text{O}$   | V.             | 1.48              | 1.5—2     |
| 24 Glaucodote          | $(\text{Fe}, \text{Co}) \text{S}_2 \cdot (\text{Fe}, \text{Co}) \text{As}_2$   | IV.            | 5.9—6             | 5         |
| 25 Glaucosite          | Al, Fe, K, Mg, Ca silicate   | Am.            | 2.2—2.4           | 2         |
| 26 Glaucophane         | $\text{Na}_2 \text{O} \cdot \text{Al}_2 \text{O}_3 \cdot 4 \text{SiO}_2 \cdot (\text{Fe}, \text{Mg}, \text{Ca}) \text{O} \cdot \text{SiO}_2$ | V.             | 3—3.1             | 6—6.5     |
| 27 Gmelinite           | $(\text{Na}_2, \text{Ca}) \text{O} \cdot \text{Al}_2 \text{O}_3 \cdot 3 \text{SiO}_2 \cdot 6 \text{H}_2 \text{O}$                            | III.rh.h.      | 2—2.1             | 4.5       |
| 28 Goethite            | $\text{FeO} \cdot \text{OH}$   | IV.            | 4—4.4             | 5—5.5     |
| 29 Gold                | Au   | I.             | 12—20             | 2.5—3     |
| 30 Gold Amalgam        | Ag, Au and Hg (Au = 40%)   | Am.            | 12—18             |           |
| 31 Goslarite           | $\text{ZnSO}_4 \cdot 7 \text{H}_2 \text{O}$  | III.rh.        | 4—4.1             | 5—5.5     |
| 32 Göthite             | $\text{Fe}_2 \text{O}_3 \cdot \text{H}_2 \text{O}$   | IV.            | 4—4.4             | 5—5.5     |
| 33 Grammatite          | See Tremolite.   |                |                   |           |
| 34 Graphic Tellurium   | $(\text{Au}, \text{Ag}) \text{Te}_2$   | V.             | 5.73—8.28         | 1.5—2     |
| 35 Graphite            | C (often with up to 5% of $\text{SiO}_2$ , &c.)  | III.           | 2                 | 1—2       |

| Lust.e.              | Colour.                          | Streak.            | Fracture.                             | Fusibility.                       | Solubility.  |                      |
|----------------------|----------------------------------|--------------------|---------------------------------------|-----------------------------------|--|----------------------|
| Vit.                 | Bl.                              | G.Gr.              | Conch.                                | Inf.                              | Gelatinous<br>SiO <sub>2</sub> with HCl  | 1                    |
| Vit. fatty<br>Met.   | G., B.<br>Lead Gr.               | W.Gr.<br>Lead Gr.  | Earthy<br>Flat, even                  | Inf.<br>Fus.                      | Ins. ac. and alk.<br>s. HNO <sub>3</sub> with<br>sepn. of S. and<br>PbSO <sub>4</sub>                | 2<br>3               |
| Vit. fatty           | Y.G., R., Br.                    | ?                  |                                       |                                   |  | 4<br>5               |
| Vit.                 | W., Y., P.,<br>pale G.           | W.                 | Flat, conch.                          | 3                                 | Gel. SiO <sub>2</sub> with<br>HCl after<br>fusion  | 6                    |
| Vit.                 | Crimson or<br>mulberry           | P.                 | Conch.                                | 3·5                               | No gel. SiO <sub>2</sub><br>with HCl<br>after fusion   | 7                    |
| Vit.                 | Hyacinth,<br>Br.R.               | W.                 | Conch.,<br>imperfect                  | Fus.                              | Decomp. HCl<br>after fusion  | 8<br>9               |
| Vit.                 | Br.G., Y.G.,<br>Br.              | W                  | Conch.                                |                                   |  | 10                   |
| Vit.                 | Emerald G.                       | G.W.               | Conch.                                | Inf.                              | Ins.   | 11                   |
| Dull                 | Apple G.—W.                      | G.                 | Earthy                                | Inf.                              | Decomp. HCl  | 12                   |
| Vit.<br>Fatty        | C., W.<br>G., Gr.G., Y.          |                    | Conch.<br>Uneven                      | 3<br>D. fus.                      | Partly s. H <sub>2</sub> O<br>Gelatinous<br>SiO <sub>2</sub> with HCl                                | 13<br>14             |
| Dull<br>Met.         | Pale, apple G.<br>Gr., Bl.       | G.<br>Gr.          | Earthy<br>∞P                          | Inf.<br>E. fus. 1·5               |  | 15<br>16             |
| Met.                 | Dark G.<br>W.—Gr.                | Gr.                | Flat                                  | E. fus.<br>S. & As.<br>volatilise | Ins. H <sub>2</sub> O<br>s. HNO <sub>3</sub> with<br>sepn. of<br>S. & As <sub>2</sub> O <sub>3</sub> | 17<br>18             |
| Vit.                 | W.Gr.                            |                    | Uneven                                | 3                                 | Gelatinous<br>SiO <sub>2</sub> with HCl  | 19<br>20             |
| Vit.<br>Vit.<br>Met. | C., Y., Gr.<br>C.<br>W.          | C.<br>C.<br>Gr.Bl. | ∞P<br>∞P ∞<br>∞P                      | 1·5<br>E. fus.<br>E. fus.         | s. H <sub>2</sub> O<br>s. H <sub>2</sub> O<br>s. HNO <sub>3</sub> with<br>sepn. of S.                | 21<br>22<br>23<br>24 |
| Dull                 | Olive G., Y.,<br>Gr., Bl.G.      | G.W.               | Earthy                                | 4                                 | Ins.   | 25                   |
| Py. vit.             | B.Gr., B., B.Bl.                 | B.Gr.              | ∞P 124°                               | E. fus.                           | Ins.   | 26                   |
| Vit.                 | Y.W., P., R.                     |                    | ∞P                                    | Fus.                              | Gelatinous<br>SiO <sub>2</sub> with HCl  | 27                   |
| Ad.<br>Met.<br>Met.  | R., Br., Bl.<br>Y.<br>W. or Y.   | Y.Br.<br>Y.<br>W.  | Conch.<br>Tough<br>Crumbles<br>easily | Inf.<br>Fus.<br>Fus.              | E.s. HCl<br>s. Aqua-regia  | 28<br>29<br>30       |
| Vit.<br>Ad.          | C., Y.<br>Y., R., Bl.Br.,<br>tl. | C.<br>Ochre Y.     | Conch.<br>Conch.                      | Inf.                              | s. H <sub>2</sub> O<br>s. HCl  | 31<br>32             |
| Met.                 | Steel Gr.—W.,<br>Y.              | Gr.—W.             | Uneven                                | Fus.                              |  | 33<br>34             |
| Met.                 | Iron Bl.                         | Bl.<br>shining     | Sectile                               | Burns                             | Ins.   | 35                   |

| Name.              | Composition.   | Cryst. System.       | Specific Gravity. | Hardness. |
|--------------------|--|----------------------|-------------------|-----------|
| 1 Gray Antimony    | See Antimonite.  |                      |                   |           |
| 2 — Copper         | See Tetrahedrite.  |                      |                   |           |
| 3 Greenockite      | CdS  | III.(h.)             | 4.8—4.9           | 3—3.5     |
| 4 Greenovite       | Titanite contg. Mn   | V.                   |                   |           |
| 5 Greenstone       | Oligoclase and Hornblende  |                      | 2.66—3.0          |           |
| 6 Green Vitriol    | See Coppéras.  |                      |                   |           |
| 7 Grossularite     | See Garnet, Lime-Alumina.  |                      |                   |           |
| 8 Grünauite        | Bi, Ni sulphides   | III.                 | 5.13              | 4.5       |
| 9 Guanajuatite     | Bi <sub>2</sub> Se <sub>3</sub>  |                      |                   |           |
| 10 Guano           | Chiefly Ca <sub>3</sub> PO <sub>4</sub> , Aq   | (Of organic origin.) |                   |           |
| 11 Guarinite       | CaO.TiSiO <sub>4</sub>   | IV.                  | 3.4—3.56          | 5—5.5     |
| 12 Guayacanite     | See Enargite.  |                      |                   |           |
| 13 Guitermannite   | PbS.PbAs <sub>2</sub> O <sub>4</sub>   | I.                   | 5.94              |           |
| 14 Gummité         | (Pb,Ca,Ba) <sub>2</sub> O.3 UO <sub>3</sub> . SiO <sub>2</sub> .5 H <sub>2</sub> O containing Ra.                      | Am.                  | 3.9—4.5           | 2.5—3     |
| 15 Gynnite, Nickel | See Genthite.  |                      |                   |           |
| 16 Gypsum          | CaSO <sub>4</sub> .2 H <sub>2</sub> O  | V.                   | 2.3               | 1.5—2     |
| 17 Hair salt       | See Epsom salt.  |                      |                   |           |
| 18 Haidingerite    | 2 CaO.As <sub>2</sub> O <sub>3</sub> .3 H <sub>2</sub> O   | IV.                  | 2.8               | 2—2.5     |
| 19 Halite          | See Rock-salt.   |                      |                   |           |
| 20 Halotrichite    | Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> .(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> . 24 H <sub>2</sub> O | I.                   | 1.71              |           |
| 21 Hamartite       | See Bastnäsite.  |                      |                   |           |
| 22 Hanksite        | Na <sub>2</sub> SO <sub>4</sub> .Na <sub>2</sub> CO <sub>3</sub>   | III.                 |                   | 3—3.5     |
| 23 Harmotome       | (K <sub>2</sub> ,Ba)O.Al <sub>2</sub> O <sub>3</sub> . 5 SiO <sub>2</sub> .5 H <sub>2</sub> O                          | V.                   | 2.3—2.5           | 4—4.5     |
| 24 Hatchettine     | CuH <sub>2</sub> n+3   | Am.                  |                   | .5—1      |
| 25 Hatchettolite   | U(NbTa)O <sub>3</sub> .H <sub>2</sub> O  | I.                   | 4.76—4.84         | 5.5       |
| 26 Hauchecornite   | (Ni,Co) <sub>2</sub> (S,Bi,Sb) <sub>4</sub>  | II.                  | 6.4               | 5         |
| 27 Hauerite        | MnS <sub>2</sub>   | I.pent.h.            | 3.46              | 4         |
| 28 Hausmannite     | Mn <sub>2</sub> O <sub>4</sub>   | II.                  | 4.72              | 5—5.5     |
| 29 Häuyine         | 5 (Na <sub>2</sub> ,Ca)O.3 Al <sub>2</sub> O <sub>3</sub> . 6 SiO <sub>2</sub> .2 SO <sub>3</sub>                      | I.                   | 2.4—2.5           | 5.5—6     |
| 30 Heavy Spar      | See Barytes.   |                      |                   |           |
| 31 Hedenbergite    | CaO.FeO.2 SiO <sub>2</sub>   | V.                   | 3.47              |           |
| 32 Hedyphane       | 3 (3 PbO.As <sub>2</sub> O <sub>3</sub> ) + PbCl <sub>2</sub> with much CaO  | Am.                  | 5.4—5.5           | 3.5—4     |
| 33 Heliotrope      | SiO <sub>2</sub> microcrystalline  |                      | 2.6—2.64          | 7         |
| 34 Helvite         | 3 SiO <sub>2</sub> .6 (Mn,Be,Fe)O. (Mn,Fe)S  | I.tetr.              | 3.1—3.3           | 6—6.5     |
| 35 Hematite, Brown | See Limonite.  |                      |                   |           |
| 36 —, Red          | Fe <sub>2</sub> O <sub>3</sub>   | III.rh. or Reniform  | 4.5—5.3           | 5.5—6.5   |
| 37 Hemimorphite*   | 2 ZnO.SiO <sub>2</sub> .H <sub>2</sub> O   | IV.                  | 3.16—3.49         | 4.5—5     |
| 38 Hercynite       | FeO.Al <sub>2</sub> O <sub>3</sub>   | I.                   | 3.91—3.95         | 7.5—8     |
| 39 Herderite       | Be(OH, F).CaPO <sub>4</sub>  | IV.                  | 3                 | 5         |
| 40 Hessite         | Ag <sub>2</sub> Te   | I.                   | 8.3—9             | 2.5—3     |
| 41 Hjelmite        | (Ca,Fe,Mn) tantalate   | IV.                  | 5.82              | 5         |

\* Hemimorphite is taken as the English name. This is the Calamine of Dana.

| Lustre.                  | Colour.  | Streak.                 | Fracture.                    | Fusibility.                                      | Solubility.   |  |
|--------------------------|--|-------------------------|------------------------------|--|---|--|
| Ad or Wax                | Honey, citron,<br>or Or.Y.<br>Rose R.<br>Gr.W.—G.W.,<br>G—Bl | Or.Y.—<br>BrickR.<br>P. | $\infty$ P<br><br>Very tough | Inf.   | s. HCl  | 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10<br>11<br>12<br>13<br>14                                  |
| Met.<br>Met.             | Gr.—W., Y<br>Y., P., W.                                      | W.                      | Brittle<br>Friable           | Fus.   | s. HNO <sub>3</sub>                                   | 15<br>16<br>17<br>18<br>19<br>20<br>21<br>22<br>23   |
| Ad.—res.                 | Br., Gr., Bl.  | C.                      | Conch.                       | Fus.   | Partly s. HCl   | 24<br>25<br>26<br>27<br>28<br>29<br>30<br>31<br>32<br>33<br>34<br>35<br>36<br>37<br>38<br>39<br>40<br>41 |
| Fatty                    | R.Y., R.Br.,<br>P.   | Y.                      | Conch.,<br>uneven            |  |   |  |
| Py.sy.,<br>ad. vit.      | C, W., Gr.,<br>R., Br.                                       | W.                      | Sectile                      | Inf.   | s. HCl and 400-<br>500 parts H <sub>2</sub> O         |  |
| Vit.                     | C.W.<br><br>Violet   | C.                      | $\infty$ P $\infty$          | E. fus.<br><br>Loses H <sub>2</sub> O<br>at 230° | s. HNO <sub>3</sub><br><br>s. H <sub>2</sub> O        |  |
| Vit.<br>Vit.             | C., W., P., Y.<br>W., Y., Gr.,<br>etc.                       | C.<br>W.                | Flat                         | Fus.<br>Fus.                                     | s. H <sub>2</sub> O<br>s. HCl                         |  |
| Wax<br>Vit. fatty        | Y W.—G.Y.<br>R.Br., Bl.Br.                                   | W.<br>Br.               | Conch.                       | Burns<br>D. fus.                                 | s. Ether<br>Decomp.<br>H <sub>2</sub> SO <sub>4</sub> |  |
| Met.                     | Y.   | Gr.Bl.                  | Conch.                       | E. fus.  | s. HNO <sub>3</sub> with<br>sepn. of S.               |  |
| Res.                     | R.Br., Br.Bl.  | Br.P.                   | $\infty$ O $\infty$          | D. fus.  | s. HCl with<br>sepn. of S.                            |  |
| Sub. met.                | Br.Bl.   | Chest-<br>nut Br.       | Uneven                       | Inf.   | s. HCl  |  |
| Vit. greasy              | B., G.B.   | C.                      | $\infty$ O                   | 3·5  | Gelatinous<br>SiO <sub>2</sub> with HCl               |  |
| Vit.<br>Ad.              | Bl., Bl.G.<br>W.   | Gr.G.<br>W.             | $\infty$ P<br>Brittle        | Fus.<br>Fus.                                     | Decomp. HCl   |  |
| Vit. res.                | G. with R. spots<br>Y., Br., G.                              |                         | Splintery<br>Uneven          | Inf.<br>E. fus.                                  | s. HF<br>Gelatinous<br>SiO <sub>2</sub> with HCl      |  |
| Met. highly<br>splendent | Iron Gr., Bl.,<br>R.   | R.                      | Sub. conch.<br>or uneven     | Inf.   | s. HCl  |  |
| Vit. ad. py.             | W., Y.Br.,<br>G., B.   | W.                      | Uneven,<br>brittle           | Almost<br>inf.                                   | Gelatinous<br>SiO <sub>2</sub> with ac.               |  |
| Vit. dull                | Bl.Gr.   | Gr.G.                   |                              | Inf.   | Ins.  |  |
| Vit.                     | Y., G.W.   | C., W.                  | Conch.                       | Fus.   | s. HCl  |  |
| det.                     | W.Gr.  | Shining                 | Conch. even                  | E. fus.  | s. hot HNO <sub>3</sub>                               |  |
| det                      | Bl.  | Bl.Gr.                  |                              |  |   |  |

| Name.                  | Composition.   | Cryst System. | Specific Gravity. | Hardness. |
|------------------------|--|---------------|-------------------|-----------|
| 1 Heulandite           | $\text{Al}_2\text{O}_3, 3 \text{ SiO}_2 + \text{CaO}, 3 \text{ SiO}_2, 5 \text{ H}_2\text{O}$      | V.            | 2.2               | 3.5—4     |
| 2 Hiddenite            | See Spodumene. (Riv als Emerald as a gem.)   |               |                   |           |
| 3 Highgate Resin       | See Copalinite.  |               |                   |           |
| 4 Hisingerite          | $2 \text{ Fe}_2\text{O}_3, 7 \text{ H}_2\text{O}, 3 \text{ SiO}_2$                                 | Am.           | 3.045             | 3         |
| 5 Homilite             | $\text{FeO}, 2 \text{ CaO}, \text{B}_2\text{O}_3, 2 \text{ SiO}_2$                                 | V.            | 3.28              | 5.5       |
| 6 Hopeite              | $\text{Zn}_3\text{PO}_4, x \text{ H}_2\text{O}$  | IV.           |                   |           |
| 7 Hornblende           | $3 (\text{Mg}, \text{Fe})\text{O}, \text{CaO}, 4 \text{ SiO}_2$                                    | V.            | 3.1—3.3           | 5—6       |
| 8 Horn Lead            | See Cromfordite.   |               |                   |           |
| 9 — Silver             | $\text{AgCl}$  | I.            | 5.5               | 1—1.5     |
| 10 — Stone             | See Flint.   |               |                   |           |
| 11 Horse Flesh Ore     | See Bornite.   |               |                   |           |
| 12 Huantajayite        | $(\text{Na}, \text{Ag})\text{Cl}$  | I.            |                   |           |
| 13 Hübnerite           | $\text{MnWO}_4$  | V.            | 7.17              |           |
| 14 Humboldtite         | See Melilite.  |               |                   |           |
| 15 Humite              | See Chondrodite.   |               |                   |           |
| 16 Huntelite           | $\text{Ag}_3\text{As}$   | Am.           | 7.47              | 2.5—3.5   |
| 17 Hureaulite          | $5 (\text{Mn}, \text{Fe})\text{O}, 2 \text{ P}_2\text{O}_5, 5 \text{ H}_2\text{O}$                 | V.            | 3.2               | 3.5       |
| 18 Hyacinth            | See Zircon.  |               |                   |           |
| 19 Hyalite             | See Opal.  |               |                   |           |
| 20 Hyalophane          | $\text{BaO}, \text{K}_2\text{O}, 2 \text{ Al}_2\text{O}_3, 8 \text{ SiO}_2$                        | V.            | 2.8—2.9           |           |
| 21 Hydrargillite       | $\text{Al}(\text{OH})_3$   | III.          | 2.3—2.4           | 2.5—3.5   |
| 22 Hydraulic Limestone | $\text{CaCO}_3$ (impure).  |               |                   |           |
| 23 Hydrocyanite        | $\text{CuSO}_4$  | IV.           | 2.4—3.0           |           |
| 24 Hydromagnesite      | $2 \text{ MgCO}_3, \text{Mg}[\text{CO}_3, (\text{OH})_2], 3 \text{ H}_2\text{O}$                   | V.            | 2.15              | 1.5—2     |
| 25 Hydronepheline      | $2 \text{ Na}_2\text{O}, 3 \text{ Al}_2\text{O}_3, 6 \text{ SiO}_2, 7 \text{ H}_2\text{O}$         | III.          | 2.25              | 5         |
| 26 Hydrophane          | See Opal.  |               |                   |           |
| 27 Hydrous Silica      | See Opal.  |               |                   |           |
| 28 Hydrozincite        | $\text{ZnCO}_3, 2 \text{ Zn}(\text{OH})_2$   |               | 3.58—3.8          | 3.5       |
| 29 Hypersthene         | $(\text{Fe}, \text{Mg})\text{O}, \text{SiO}_2$   | IV.           | 3.3               | 5—6       |
| 30 Ice                 | $\text{H}_2\text{O}$   | III.rh.h.     | 0.9145            | 1.5       |
| 31 Iceland Spar        | See Calcite.   |               |                   |           |
| 32 Ice Stone           | See Cryolite.  |               |                   |           |
| 33 Idocrase            | $\text{Ca}_3[\text{Al}(\text{OH}, \text{F})]\text{Al}_2(\text{SiO}_4)_2$                           | II.           | 3.34—3.45         | 6.5       |
| 34 Idrialite           | Resin with $\text{HgS}$  | Am.           | 1.4—1.6           | 1—1.5     |
| 35 Ilesite             | $\text{MnSO}_4, (\text{Zn}, \text{Fe})\text{SO}_4, \text{H}_2\text{O}$                             | IV.           |                   |           |
| 36 Ilmenite            | $\text{FeO}, \text{TiO}_2$   | III.rh.t.     | 4.5—5.1           | 5—6       |
| 37 Ilvaite             | $(\text{Ca}, \text{Fe})\text{O}, \text{Fe}_2\text{O}_3, 2 \text{ SiO}_2$                           | IV.           | 3.7—4.2           | 5.5—6     |
| 38 Indicolite          | Tourmaline (q.v.)  |               |                   |           |
| 39 Infusorial Earth    | See Tripolite.   |               |                   |           |
| 40 Iodide of Mercury   | $\text{HgI}_2$   | Am            |                   |           |
| 41 — — Silver          | $\text{AgI}$   | III.          | 5.5—5.7           | 1—1.5     |
| 42 Iodobromite         | $\text{Ag}(\text{Cl}, \text{Br}, \text{I})$  | I.            |                   |           |
| 43 Iodyrite            | $\text{AgI}$ (See iodide of silver).   |               |                   |           |
| 44 Iolite              | $4 (\text{Mg}, \text{Fe})\text{O}, 4 \text{ Al}_2\text{O}_3, 10 \text{ SiO}_2, \text{H}_2\text{O}$ | IV            | 2.6—2.7           | 7—7.5     |

| Lustre.     | Colour.                  | Streak.          | Fracture.          | Fusibility.      | Solubility.  |                |
|-------------|--------------------------|------------------|--------------------|------------------|--|----------------|
| Vit. py.    | C.W.R.Br.<br>Emerald G.  | W.               | Conch.,<br>brittle | Fus.             | s. ac.   | 1<br>2<br>3    |
| Greasy—vit. | Bl.—Br.Bl.               | Y.Br.            | Earthy             | Inf.             |  | 4              |
| Wax. vit.   | Bl., Bl.Br.              | Gr.Br.           |                    | E. fus.          | E.s. HCl   | 5              |
| Res.        | Gr.W.                    | W.               |                    |                  | s. HCl   | 6              |
| Vit.        | Bl., Bl.G.,<br>Bl.Gr.    | G.Gr.            | ∞P 124°            | E. fus.          |  | 7              |
| Res. ad.    | C., Gr., G.,<br>Bl.      | Shining          | Sectile            | Fus. gives<br>Ag | s. NH <sub>4</sub> OH  | 8<br>9         |
|             | C.                       |                  |                    | Fus.             | H <sub>2</sub> O decom-<br>poses it                          | 10<br>11<br>12 |
| Vit.        | Br.Bl., R.tr.            | R.Br.            | ∞P ∞               | Fus.             | s. HCl   | 13<br>14       |
| Met.        | Gr.—Bl.                  | Gr.              | Brittle            | Fus.             | s. HNO <sub>3</sub>  | 15             |
| Greasy      | R.—Br. Or.               | Y.Br.            | Conch.,<br>uneven  | E. fus.          | E.s. HNO <sub>3</sub>  | 16<br>17       |
|             | R.tr.                    |                  |                    |                  |  | 18<br>19<br>20 |
| Py.         | W., C., Gr.              |                  |                    | Inf.             | d.s. hot HCl   | 21<br>22       |
| Vit.        | G., Br., B.              | W.               | Conch.             | Inf.             | s. H <sub>2</sub> O  | 23             |
| Dull        | W., Gr.                  |                  | Earthy             | Inf.             | s. HCl   | 24             |
| Vit.        | C., W., Gr.              |                  | Uneven             | 2                | Gelatinous<br>SiO <sub>2</sub> with HCl                      | 25<br>26<br>27 |
| Dull        | W.Y.                     |                  |                    | Inf.             | s. HCl, HNO <sub>3</sub>                                     | 28             |
| Py. met.    | Br.G., Gr.,<br>G.Bl., R. | Gr.,<br>Br.Gr.   | Uneven             | Fus.             | Ins.   | 29             |
| Vit.        | C., W., B.               | C.               | Conch.             | 0° C.            |  | 30<br>31<br>32 |
| Vit. res.   | Br., G., Y.,<br>Str.Stl. | W.               | Sub. conch.        | Fus. 3           | Gelatinous<br>SiO <sub>2</sub> with HCl                      | 33             |
| Res.        | Gr., Br., R.<br>W., Y.   | R.Br., Bl.<br>W. | Flaky              | 300°             | s. hot H <sub>2</sub> SO <sub>4</sub><br>s. H <sub>2</sub> O | 34<br>35       |
| Met.        | Gr.Bl.                   | Bl.              | Conch.             | 6                | d.s. HCl with<br>sepn. of TiO <sub>2</sub>                   | 36             |
| Vit.        | Bl.—Gr.<br>B., B.Bl.     | Gr.              | Conch.             | Fus.             |  | 37<br>38<br>39 |
| Dull        | R.Br.                    | R.               | Earthy             | Fus.             |  | 40             |
| Ad. greasy  | Gr., Y.                  |                  | oP                 | E. fus.          | s. NH <sub>4</sub> OH  | 41             |
| Res. ad.    | Y.                       | Y.               |                    | Fus.             | s. NH <sub>4</sub> OH  | 42<br>43       |
| Vit.        | B., Gr.B., Y.            | C.               |                    | D. fus. 5        | Ins.   | 44             |



| Name.                       | Composition.   | Cryst. System.             | Specific Gravity. | Hardness. |
|-----------------------------|--|----------------------------|-------------------|-----------|
| 1 Iridium                   | Ir(Pt, Fe)   | I.                         | 22.6—22.8         | 6—7       |
| 2 Iridosmine                | IrOs(Pt, Rh, Ru, &c.)  | III. rh. h.                | 19.3—21.0         | 6—7       |
| 3 Iron, Magnetic            | See Magnetite.   |                            |                   |           |
| 4 —, Native                 | Fe   | I.                         | 7.3—7.8           | 4.5       |
| 5 — Pyrites                 | FeS <sub>2</sub>   | I.                         | 4.8—5.2           | 6—6.5     |
| 6 — Sinter                  | Fe <sub>2</sub> O <sub>3</sub> .As <sub>2</sub> O <sub>5</sub> .aq                                       | Am.                        | 3.1—3.3           | 3.5—4     |
| 7 — Titanic                 | See Ilmenite.  |                            |                   |           |
| 8 Ironstone, Clay           | See Limonite (Nodular form).   |                            |                   |           |
| 9 Iserrine                  | See Ilmenite.  |                            |                   |           |
| 10 Jade                     | See Tremolite  |                            |                   |           |
| 11 Jamesonite               | 2 PbS.Sb <sub>2</sub> S <sub>3</sub>   | IV.                        | 5.5—5.7           |           |
| 12 Jargon                   | See Zircon.  |                            |                   |           |
| 13 Jasper                   | Impure SiO <sub>2</sub>  |                            |                   |           |
| 14 Jet                      | Like cannel coal   | Am.                        |                   | 2—3       |
| 15 Johannite                | See Uranvitriol.   |                            |                   |           |
| 16 Kainite                  | KCl.MgSO <sub>4</sub> .3 H <sub>2</sub> O  | V.                         | 2.13              | 2         |
| 17 Kakoxene                 | 2 Fe <sub>2</sub> O <sub>3</sub> .P <sub>2</sub> O <sub>5</sub> .12 H <sub>2</sub> O                     | V. or VI.                  | 2.3—2.4           | 3—3.5     |
| 18 Kalaite                  | See Turquoise (contains Cu and Fe).  | I. pent. h.                | 1.75              | 2—2.5     |
| 19 Kalinite                 | K <sub>2</sub> SO <sub>4</sub> .Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> .<br>24 H <sub>2</sub> O |                            |                   |           |
| 20 Kampylite                | 3 (3 PbO.As <sub>2</sub> O <sub>5</sub> )PbCl <sub>2</sub>   | (Barrel-shaped crystals of |                   |           |
| 21 Kaneite                  | MnAs <sub>2</sub>  | I.                         | 5.55              |           |
| 22 Kaolin                   | Al <sub>2</sub> O <sub>3</sub> .2 H <sub>2</sub> O.2 SiO <sub>2</sub>                                    | V.                         | 2.2—2.6           | 1         |
| 23 Karpbolite               | (Mn, Fe)O.(Fe, Al) <sub>2</sub> O <sub>3</sub> .<br>SiO <sub>2</sub> .2 H <sub>2</sub> O                 | V.                         | 2.9               | 5         |
| 24 Katapleite               | (Na <sub>2</sub> , Ca)O.ZrO <sub>2</sub> .<br>3 SiO <sub>2</sub> .2 H <sub>2</sub> O                     | V. and III.<br>(at 140°)   | 2.8               | 6         |
| 25 Keilhauite               | Sphene with 9.6% Y.  | V.                         | 3.69              | 6.5       |
| 26 Kermesite                | 2 Sb <sub>2</sub> S <sub>3</sub> .Sb <sub>2</sub> O <sub>3</sub>   | IV.                        |                   |           |
| 27 Kidney Ore               | See Hematite, Red.   |                            |                   |           |
| 28 Kieselguhr (Diatom Mud.) | Siliceous remains of diatoms   | Am.                        |                   |           |
| 29 Kieserite                | MgSO <sub>4</sub> .H <sub>2</sub> O  | V.                         | 2.5—2.6           | 3         |
| 30 Koppite                  | (Ca, Ce, Fe, Hg, Na) <sub>2</sub> O.<br>NbO <sub>2</sub> .H <sub>2</sub> O                               | I.                         | 4.45—4.56         |           |
| 31 Krennerite               | (Au, Ag)Te <sub>2</sub>  | IV.                        | 8.35              | 2.5—3     |
| 32 Krokydolite              | Na <sub>2</sub> O.Fe <sub>2</sub> O <sub>3</sub> .4 SiO <sub>2</sub> .<br>FeO.SiO <sub>2</sub>           | V.                         | 3.2               | 4         |
| 33 Kupfernickel             | NiAs   | III.                       | 7.3—7.6           | 5—5.5     |
| 34 Kyanite                  | Al <sub>2</sub> O <sub>3</sub> .SiO <sub>2</sub>   | VI.                        | 3.6—3.7           | 5—7       |
| 35 Labradorite              | Ab <sub>1</sub> An <sub>1</sub> —Ab <sub>1</sub> An <sub>3</sub> *                                       | VI.                        | 2.67—2.76         | 6         |
| 36 Lanarkite                | PbSO <sub>4</sub> .PbCO <sub>3</sub>   | V.                         | 6.3—7             | 2—2.5     |
| 37 Langite                  | CuSO <sub>4</sub> .aq  | IV.                        | 3.48—3.5          | 4         |
| 38 Lanthanite               | La <sub>2</sub> (CO <sub>3</sub> ) <sub>3</sub> .9 H <sub>2</sub> O                                      | IV.                        | 2.6—2.7           | 2         |
| 39 Lapis Lazuli             | Near Häuyine   | I.                         | 2.38—2.45         | 5—5.5     |
| 40 Laumonite                | CaO.Al <sub>2</sub> O <sub>3</sub> .4 SiO <sub>2</sub> .<br>2 H <sub>2</sub> O                           | V                          | 2.3               | 3.5       |
| 41 Lawsonite                | CaO.Al <sub>2</sub> O <sub>3</sub> .2 SiO <sub>2</sub> .<br>2 H <sub>2</sub> O                           | IV                         | 3.1               | 8.5       |

\*Ab=Albite; An=Anorthite.



| Lustre.                  | Colour.                     | Streak.      | Fracture.            | Fusibility.                                 | Solubility.   |    |
|--------------------------|-----------------------------|--------------|----------------------|---|---|----|
| Met.                     | W.Gr.                       | Gr.          | $\infty$ O $\infty$  | Inf.  | Ins.  | 1  |
| Met.                     | W.                          |              | oP.                  | Inf.  | Ins.  | 2  |
|                          |                             |              |                      |   |   | 3  |
| Met.                     | Gr.Bl.                      | Gr.          | Hackly               | Fus   | s. ac.  | 4  |
| Met.                     | Y. (Brass)                  | Gr. Br.Bl.   | Brittle              | Gives off S.                                |   | 5  |
| Vit.—sub.<br>ad.         | P. leek G. or<br>liver Br.  | Br.          | Friable              |   |   | 6  |
|                          |                             |              |                      |   |   | 7  |
|                          |                             |              |                      |   |   | 8  |
|                          |                             |              |                      |   |   | 9  |
|                          |                             |              |                      |   |   | 10 |
|                          | Lead Gr.                    |              | Fibrous              |   |   | 11 |
|                          | C. & smoky-<br>tinted       |              |                      |   |   | 12 |
| Splendent                | R., Br., Y., op.<br>Bl.     | Bl.          | Conch.               | Burns                                       |   | 13 |
|                          |                             |              |                      |   |   | 14 |
| Vit.                     | C., Gr., Y.                 |              | $\infty$ P $\infty$  |   | s. H <sub>2</sub> O   | 15 |
| Sy.                      | Y.                          | Y.           | Fibrous              | Fus.  | s. HCl  | 16 |
|                          |                             |              |                      |   |   | 17 |
| Vit.                     | C.                          | C.           |                      | E. fus.                                     | E.s. H <sub>2</sub> O   | 18 |
|                          |                             |              |                      |   |   | 19 |
| Mimetite.)<br>Met.       | Br.Y.<br>Gr.W.              | Gr.          |                      | Gives off<br>As <sub>2</sub> O <sub>3</sub> |   | 20 |
|                          |                             |              |                      |   |   | 21 |
| Dull                     | W.                          | W.           | Earthy               | Inf.  | s.hot H <sub>2</sub> SO <sub>4</sub><br>with sepn.<br>of SiO <sub>2</sub> | 22 |
| Sy.                      | Y., G.Y.                    | Y.           | Fibrous              | 3·5   | Ins.  | 23 |
| Vit.                     | Y., Y.Br., P.,<br>Gr.B., V. |              | $\infty$ P.          | E. fus.                                     | Gelatinous<br>SiO <sub>2</sub> with HCl                                   | 24 |
| Res.—dull<br>Ad.         | Br.Bl.<br>R.                | Br.Bl.<br>R. | Powders<br>Conch     | E. fus.<br>E. fus.                          | s. HNO <sub>3</sub>   | 25 |
|                          |                             |              |                      |   |   | 26 |
| Dull                     | W.Y.                        |              | Earthy               | Inf.  | s. HF, KOH  | 27 |
|                          |                             |              |                      |   |   | 28 |
| Vit.                     | W., Y., Gr.                 | W.           | Conch.               | E. fus.                                     | s. H <sub>2</sub> O   | 29 |
| Vit.                     | Br.                         | Y.           |                      |   |   | 30 |
| Met.                     | Y.W.                        | Shining      | oP.                  | Decrepi-<br>tates                           | Decomp.<br>HNO <sub>3</sub>   | 31 |
| Sy.                      | B.G.                        | B.Gr.        | Fibrous              | E. fus.                                     | Ins.  | 32 |
| Met.                     | Copper R., pale             | Br.Bl.       | Uneven               | Fus.  | s. Aqua-regia   | 33 |
| Py.                      | W., B.                      | W.           | Brittle              | Inf.  |   | 34 |
| Vit. py. or<br>sub. res. | Gr., Br., G.,<br>R., B.     | C., W.       | Uneven,<br>splintery | Fus.  | s. hot HCl  | 35 |
| Py, greasy               | W., Y., Gr., G              | W.           | oP.                  | Fus.  | Decomp.HNO <sub>3</sub>   | 36 |
| Vit.                     | B., G.                      | W.           | Conch.               |   | s. H <sub>2</sub> O   | 37 |
| Dull, py.                | W., Y., P.                  |              | oP.                  | Inf.  | s. HCl  | 38 |
| Vit.                     | Azure B.                    | B.           | Uneven               | Fus.  | Gelatinous<br>SiO <sub>2</sub> with HCl                                   | 39 |
| Vit. py.                 | W., Y.                      | W.           | Friable              | E. fus.                                     | Gelatinous<br>SiO <sub>2</sub> with HCl                                   | 40 |
| Vit.                     | C.                          | C.           | Uneven               | E. fus.                                     | Gelatinous<br>SiO <sub>2</sub> with HCl<br>after fusion                   | 41 |

| Name.                | Composition.   | Cryst. System.       | Specific Gravity. | Hardness.        |
|----------------------|--|----------------------|-------------------|------------------|
| 1 Lāvenit            | (Mn,Ca,Fe)O.(ZrO,F)<br>Na <sub>2</sub> O.2 SiO <sub>2</sub>  | V.                   | 3.51—3.55         | 6                |
| 2 Lazulite           | (Mg,Fe,Ca) (Al,OH) <sub>2</sub><br>P <sub>2</sub> O <sub>5</sub>   |                      | 3—3.12            | 5—6              |
| 3 Leadhillite        | 4 PbSO <sub>4</sub> .2 CO <sub>3</sub> .H <sub>2</sub> O   | V.                   | 6.3—6.5           | 2.5              |
| 4 Lehrbachite        | PbSe + HgSe  | I.                   | 7.1—7.8           | Soft             |
| 5 Lepidokrokite      | See Göthite.   |                      |                   |                  |
| 6 Lepidolite         | Al <sub>2</sub> O <sub>3</sub> .3 SiO <sub>2</sub> .(Li,K) <sub>2</sub><br>(F,OH) <sub>2</sub>                               | V.                   | 2.84—3            | 2 elastic        |
| 7 Lepidomelane       | (K,H) <sub>2</sub> O.(Fe,Al) <sub>2</sub> O <sub>3</sub> .<br>2 (Fe,Mg)O.3 SiO <sub>2</sub>                                  | V.                   | 3                 | 2.5—3<br>elastic |
| 8 Leucite            | K <sub>2</sub> O.Al <sub>2</sub> O <sub>3</sub> .4 SiO <sub>2</sub>  | I. & IV.             | 2.44—2.56         | 5.5—6            |
| 9 Leucophanite       | NaF.CaO.BeO.2 SiO <sub>2</sub>   | IV.h.                | 2.97              | 3.5—4            |
| 10 Leucopyrites      | FeAs <sub>2</sub>  | IV.                  | 6.8—8.71          | 5—5.5            |
| 11 Levyn             | CaO.Al <sub>2</sub> O <sub>3</sub> .3 SiO <sub>2</sub> .<br>5 H <sub>2</sub> O   | III.rh.h.            | 2.1—2.2           | 4                |
| 12 Libethenite       | 4 CuO.P <sub>2</sub> O <sub>5</sub> .H <sub>2</sub> O  | IV.                  | 3.6—3.8           | 4                |
| 13 Lièvrite          | (Ca,Fe)O.Fe <sub>2</sub> O <sub>3</sub> .SiO <sub>2</sub>  | IV.                  | 3.9—4.1           | 5.5—6            |
| 14 Lignite           | New coal. (Contains  | larger percentage of |                   | H and C          |
| 15 Limestone         | CaCO <sub>3</sub> in beds  |                      |                   |                  |
| 16 Limonite          | 2 Fe <sub>2</sub> O <sub>3</sub> .3 H <sub>2</sub> O   | Am.                  | 3.6—4             | 5—5.5            |
| 17 Linarite          | PbSO <sub>4</sub> .Cu(OH) <sub>3</sub>   | V.                   | 5.3—5.45          | 2.5—3            |
| 18 Linnaeite         | (Co,Ni) <sub>3</sub> S <sub>4</sub>  | I.                   | 4.8—5.0           | 5.5              |
| 19 Lionite           | Impure native Te(q.v.)   |                      |                   |                  |
| 20 Liroconite        | 2 Al <sub>2</sub> O <sub>3</sub> .2 As <sub>2</sub> O <sub>5</sub> .<br>7 Cu(OH) <sub>2</sub> .2 CuO.<br>20 H <sub>2</sub> O | V.                   | 2.88—2.98         | 2—2.5            |
| 21 Lithia Mica       | See Lepidolite.  |                      |                   |                  |
| 22 Lithomarge        | K <sub>2</sub> O.Al <sub>2</sub> O <sub>3</sub> .6 SiO <sub>2</sub> aq   | Am.                  |                   | 1.5—2            |
| 23 Liver Ore         | See Cinnabar.  |                      |                   |                  |
| 24 Livingstonite     | Antimonite (q.v.) with<br>14% Hg   |                      |                   |                  |
| 25 Lodestone         | See Magnetite.   |                      |                   |                  |
| 26 Löllingite        | Fe <sub>2</sub> As <sub>3</sub>  | IV.                  | 6.2—7.45          | 5—5.5            |
| 27 Loranskite        | See Euxenite.  |                      | 4.6               | 5                |
| 28 Lovenite          | (Zr,Ca,Na) <sub>2</sub> O.SiO <sub>2</sub>   | V.                   |                   |                  |
| 29 Löweite           | 2 MgSO <sub>4</sub> .2 Na <sub>2</sub> SO <sub>4</sub> .<br>5 H <sub>2</sub> O   | II.                  | 2.37              | 2.5—3            |
| 30 Ludlamite         | Fe <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> aq   | V.                   |                   |                  |
| 31 Ludwigite         | 3 MgO.B <sub>2</sub> O <sub>3</sub> + Fe <sub>3</sub> O <sub>4</sub>   | IV.                  | 3.9—4.1           | 5                |
| 32 Lydian Stone      | Jasper (q.v.). [Velvet-  | black variety.       |                   | Used for         |
| 33 Magnesia Mica     | See Biotite.   |                      |                   |                  |
| 34 Magnesite         | MgCO <sub>3</sub>  | III.rh.              | 3                 | 3.5—4.1          |
| 35 Magnetic Iron Ore | See Magnetite.   |                      |                   |                  |
| 36 Magnetic Pyrites  | See Pyrrhotine.  |                      |                   |                  |
| 37 Magnetite         | FeO.Fe <sub>2</sub> O <sub>3</sub> or Fe <sub>3</sub> O <sub>4</sub>   | I.                   | 4.9—5.2           | 5.5—6.5          |
| 38 Magnolite         | Hg <sub>2</sub> TeO <sub>4</sub>   | V.                   |                   | 5.5              |
| 39 Malachite, Blue   | See Azurite  |                      |                   |                  |
| 40 —, Green or true  | CuCO <sub>3</sub> .Cu(OH) <sub>2</sub>   | V.                   | 3.7—4             | 3.5—4            |
| 41 Malacolite        | White Augite (q.v.).   |                      |                   |                  |

| Lustre.             | Colour.                  | Streak. | Fracture.              | Fusibility.        | Solubility.                             |    |
|---------------------|--------------------------|---------|------------------------|--------------------|---|----|
| Vit.                | C., Y., R.Br.,<br>Bl.Br. | Br.Y.   | $\infty P \infty$      | E. fus.            | Decomp. hot<br>$H_2SO_4$                | 1  |
| Vit.                | B.                       |         | Uneven                 | Inf.               | s. HCl after<br>heating                 | 2  |
| Greasy ad.          | Y.W., Gr., Br.           |         | oP.                    | Fus.               | s. $HNO_3$ with<br>sepn. of $PbSO_4$    | 3  |
| Met.                | Gr., Gr.Bl.              | G.      | $\infty O \infty$      | Sublimes           |   | 4  |
| Py.                 | P.                       | P.      | oP.                    | 2—2.5              | Decomp. HCl<br>after fusion             | 5  |
| Py.                 | Bl.                      | Gr.     | oP.                    | 4                  | Decomp. HCl<br>with formn<br>of $SiO_2$ | 6  |
| Vit.                | W., Gr., tl.op.          | W.C.    | Brittle                | Inf.               | s. HCl                                  | 7  |
| Vit. greasy         | G., G.Y., C.,<br>W.      | Y.W.    | oP.                    | Fus.               | s. HF                                   | 8  |
| Met.                | Silver W.                | Gr.Bl.  | Brittle                | $As_2O_3$<br>fumes |   | 9  |
|                     | C.                       |         | Flat                   | 3                  | Gelatinous<br>$SiO_2$ with HCl          | 10 |
| Greasy              | Olive G.                 | G.      | Uneven                 | 2                  | s. $HNO_3$                              | 11 |
| Vit. greasy         | Bl., Br.Bl.,<br>G.Bl.    | Bl.     | Conch.,<br>uneven      | 2.5                | Gelatinous<br>$SiO_2$ with HCl          | 12 |
| than anthra         | cite.)                   |         |                        |                    |   | 13 |
| Sub.met., sy        | Br., Y.                  | Y.Br.   | Earthy                 | Inf.               | s. HCl                                  | 14 |
| Ad.                 | Azure B.                 | Pale B. | $\infty P \infty$ , oP | Fus.               | s. $HNO_3$ with<br>sepn of $PbSO_4$     | 15 |
| Met.                | Steel Gr.—R.             | Bl.Gr   | Brittle                | Fus.               | s. $HNO_3$                              | 16 |
| Vit fatty           | B., G                    | G., B.  | Uneven                 | Fus.               | s. $HNO_3$ and<br>$NH_4OH$              | 17 |
|                     |                          |         |                        |                    |   | 18 |
| Greasy              | W., Y., R.               | Shining |                        | Inf.               | Ins.                                    | 19 |
|                     |                          | R.      |                        |                    |   | 20 |
|                     |                          |         |                        |                    |   | 21 |
| Met.                | W., Gr.                  | Bl.     | oP                     | D. fus.            | s. $HNO_3$ with<br>sepn. of $As_2O_3$   | 22 |
|                     |                          |         |                        |                    |   | 23 |
|                     | Br., Y.                  | Y.Br.   |                        |                    |   | 24 |
| Vit.                | W., Y., R.               | W.      |                        | Fus.               | s. $H_2O$                               | 25 |
|                     | G.                       |         |                        |                    |   | 26 |
|                     | Bl.G., Bl.               | ?       |                        | 6                  | E.s. HCl                                | 27 |
| trying purity       | of gold alloys.          |         |                        |                    |   | 28 |
| Vit, dull, sy.      | W., Gr.W., Y.,<br>Br.    | W.      | Even                   | Inf.               | s. hot HCl                              | 29 |
|                     |                          |         |                        |                    |   | 30 |
| Met. or<br>sub-met. | Iron Bl. op.             | Bl.     | Sub. conch.            | 6                  | s. HCl                                  | 31 |
| Sy.                 | W.                       | W.      |                        |                    |   | 32 |
| Ad. vit. sy.        | Bright G.<br>W., Gr.     | Pale G. |                        | Fus.               | s. HCl, $HNO_3$                         | 33 |
|                     |                          |         |                        |                    |   | 34 |
|                     |                          |         |                        |                    |   | 35 |
|                     |                          |         |                        |                    |   | 36 |
|                     |                          |         |                        |                    |   | 37 |
|                     |                          |         |                        |                    |   | 38 |
|                     |                          |         |                        |                    |   | 39 |
|                     |                          |         |                        |                    |   | 40 |
|                     |                          |         |                        |                    |   | 41 |

|    | Name.            | Composition.   | Cryst. System. | Specific Gravity. | Hardness. |
|----|------------------|--|----------------|-------------------|-----------|
| 1  | Malacon          | Partially decomposed Zirkon contg. Ce, Y, Th, Fe, Ca, Mg, 3-9% H <sub>2</sub> O            | II.            | 3.9-4.1           | 6         |
| 2  | Mallardite       | MnSO <sub>4</sub> ·7 H <sub>2</sub> O  | V.             |                   | 3.5       |
| 3  | Manganblende     | See Alabandin.   |                |                   |           |
| 4  | Manganepidote    | H <sub>2</sub> O.4 CaO.<br>3 (Al, Mn) <sub>2</sub> O <sub>3</sub> .6 SiO <sub>2</sub>      | V.             | 3.4               | 6.5       |
| 5  | Manganese Spar   | See Rhodonite.   |                |                   |           |
| 6  | Manganite        | Mn <sub>2</sub> O <sub>3</sub> ·H <sub>2</sub> O   | IV.            | 4.2-4.4           | 4         |
| 7  | Manganosite      | MnO  | I.             | 5.18              | 5-6       |
| 8  | Manganostilbite  | MnS with As <sub>2</sub> S <sub>3</sub> and Sb <sub>2</sub> S <sub>3</sub>                 |                |                   |           |
| 9  | Manganotantalite | MnO.Ta <sub>2</sub> O <sub>5</sub> , with Sn & W   | IV.            | 7-8               | 6-6.5     |
| 10 | Marble           | CaCO <sub>3</sub>  |                |                   |           |
| 11 | Marcasite        | FeS <sub>2</sub>   | IV.            | 4.6-4.85          | 6-6.5     |
| 12 | Margarite        | CaO.2 Al <sub>2</sub> O <sub>3</sub> .2 SiO <sub>2</sub> .<br>H <sub>2</sub> O             | IV.            | 2.99              | 3.5-4.5   |
| 13 | Marialite        | 2 NaCl, 3 Na <sub>2</sub> O.<br>3 Al <sub>2</sub> O <sub>3</sub> , 18 SiO <sub>2</sub>     | II.pyr.h.      | 2.57              | 5.5-6     |
| 14 | Martite          | See Hematite. (Octahedral.)  |                |                   |           |
| 15 | Mascagnine       | (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>  | IV.            | 1.7-1.8           | 2-2.5     |
| 16 | Masonite         | See Chloritoid.  |                |                   |           |
| 17 | Matlockite       | PbO.PbCl <sub>2</sub>  | IV.            | 7.2               | 2.5-3     |
| 18 | Maxite           | See Leadhillite.   |                |                   |           |
| 19 | Meerschaum       | See Sepiolite.   |                |                   |           |
| 20 | Mejonite         | 4 CaO.3 Al <sub>2</sub> O <sub>3</sub> .6 SiO <sub>2</sub>                                 | II.pyr.h.      | 2.7-2.8           | 5.5-6     |
| 21 | Melaconite       | CuO  | Am.            | 6.25              | 3         |
| 22 | Melanite         | See Garnet, Iron-lime.   |                |                   |           |
| 23 | Melanocerite     | Ce and Y fluosilicate with C, B, Ta, &c.   | III.rh.        | 4.15              | 5.5-6     |
| 24 | Melanochroite    | PbCrO <sub>4</sub> , impure  | ?              | 5.75              |           |
| 25 | Melanosiderite   | Fe <sub>2</sub> O <sub>3</sub> ·xH <sub>2</sub> O.<br>7.42% SiO <sub>2</sub>               | Am.            |                   |           |
| 26 | Melanterite      | See Copperas.  |                |                   |           |
| 27 | Meliphanite      | 2 (Mg, Fe)O.SiO <sub>2</sub><br>contg. Be  | IV.            | 3.018             | 6-7       |
| 28 | Melinophane      | See Meliphanite.   |                |                   |           |
| 29 | Melilite         | 6 (Ca, Mg, Na <sub>2</sub> )O.<br>(Al, Fe) <sub>2</sub> O <sub>3</sub> .5 SiO <sub>2</sub> | II.            | 2.9-3.1           | 5-5.5     |
| 30 | Melonite         | NiTe   | III.           |                   | 5-5.5     |
| 31 | Menaccanite      | See Ilmenite.  |                |                   |           |
| 32 | Mendipite        | 2 PbO.PbCl <sub>2</sub>  | IV.            | 7-7.1             | 2.5-3     |
| 33 | Mendozite        | See Alun, Soda.  |                |                   |           |
| 34 | Meneghinite      | 4 PbS.Sb <sub>2</sub> S <sub>3</sub>   | IV.            | 6.3               | 3         |
| 35 | Menilite         | Opal (reniform)  | Am.            |                   |           |
| 36 | Mercury          | Hg   | I. (-40°C.)    | 13.56             |           |

| Lustre.      | Colour.                        | Streak.   | Fracture.      | Fusibility.            | Solubility.  |          |
|--------------|--------------------------------|-----------|----------------|------------------------|--|----------|
|              | B.W., Br., Bl.                 |           |                | Inf.                   |  | 1        |
| Vit.         | W., P., Y.                     | W.        |                | Fus.                   | s. H <sub>2</sub> O  | 2        |
| Vit.         | Dark R.                        | R.        | oP.            | E. fus.                | Gel. SiO <sub>2</sub> with HCl after heating to redness.               | 3<br>4   |
| Sub-met.     | Bl.Gr.op.                      | R.Br.—Bl. | Uneven         | Loses H <sub>2</sub> O | s. HCl   | 5<br>6   |
| Vit.         | Emerald G.—Br.                 | G.        |                | Inf.                   |  | 7<br>8   |
| Sub-met.     | Br.Bl.                         | Br.R.     | Brittle        | Inf.                   |  | 9<br>10  |
| Met.         | W., P., or streaked Whitish Y. | Br.Bl.    | Brittle        | Fus.                   | s. HNO <sub>3</sub> with sepn. of S                                    | 11       |
| Py. vit.     | W., P.W., Y., Gr.              | W., P.W.  | Mica-like      | D. fus.                | Ins.   | 12       |
| Vit.         | G.W., Gr.                      |           | ∞ P ∞          | 3                      | Ins.   | 13       |
| Vit.         | Y.Gr., tl.—op.                 | C.        | oP.            | E.fus. volatilises     | E.s. H <sub>2</sub> O  | 14<br>15 |
| Ad.          | G.Y.                           | W.G.      | Conch., uneven | E. fus.                | s. HNO <sub>3</sub>  | 16<br>17 |
| Vit.         | C., W., Gr.                    |           | ∞ P ∞          | 3                      | Decomp. HCl  | 18<br>19 |
| Dull         | Bl.                            | Bl.       | Earthy         | Inf.                   | s. ac.   | 20<br>21 |
| Dull or vit. | Bl.                            |           |                |                        |  | 22       |
| Greasy vit.  | Br.Bl.                         | Br.       | Conch.         | Inf.                   | s. hot HCl with sepn. of SiO <sub>2</sub>                              | 23       |
| Vit.         | Dark R.                        | Brick R.  | Conch.         | Fus.                   | Gelatinous SiO <sub>2</sub> with HCl                                   | 24<br>25 |
| Vit.         | Br.R.                          | Br.       |                |                        |  | 26       |
| Vit.         | Y.                             | Y.        |                | Inf.                   | Decomp. HCl  | 27       |
| Vit. wax.    | C., W., Y., Br.                | W.        | oP.            | Fus.                   | Gelatinous SiO <sub>2</sub> with HCl                                   | 28<br>29 |
| Met.         | R.W.                           | P.W.      |                |                        |  | 30       |
| Py.          | W., Y., R.op.                  | W.        | ∞ P.           | E. fus.                | E.s. HNO <sub>3</sub>  | 31<br>32 |
| Met.         | W.Gr.                          | Gr.       |                | E. fus.                | s. HNO <sub>3</sub> with sepn. of S and Sb <sub>2</sub> O <sub>3</sub> | 33<br>34 |
| Met.         | Br.op.                         |           | Liquid.        | Volatilises            | s. HNO <sub>3</sub>  | 35       |
| splendent    | W.op                           |           |                |                        |  | 36       |

|    | Name.            | Composition.  | Cryst. System. | Specific Gravity. | Hardness. |
|----|------------------|---|----------------|-------------------|-----------|
| 1  | Mercury Sulphide | See Cinnabar.   |                |                   |           |
| 2  | Meraxene         | $(K,H)_2O.(Fe,Al)_2O_3$<br>$2 (Fe,Mg)O.3 SiO_2$                               | V.             | 2.8—3.2           | 2         |
| 3  | Mesitine Spar.   | $(Mg,Fe)CO_3$   | III.rh.h.      | 3.3—3.4           | 3.5—4     |
| 4  | Mesolite         | $Na_2O.Al_2O_3.3 SiO_2$<br>$2 H_2O$<br>$Ca(OH)_2.Al_2O_3.3 SiO_2$<br>$2 H_2O$ | V.             | 2.2—2.4           | 5         |
| 5  | Mesotype         | See Natrolite.  |                |                   |           |
| 6  | Metacinnabarite  | HgS   | I.tetr.h.      | 7.7—7.8           | 3         |
| 7  | Miargyrite       | $Ag_2S.Sb_2S_3$   | V.             | 5.2—5.4           | 2—2.5     |
| 8  | Mica             | (See Muscovite, Biotite, Lepidolite, Phlogopite, &c.)                         |                |                   |           |
| 9  | Microcline       | $K_2O.Al_2O_3.6 SiO_2$  | VI.            | 2.5—2.6           | 6         |
| 10 | Microlite        | $2 [Ca,Mn,Fe,Mg]O$<br>$[Ta,Nb]_2O_5$  | I.             | 5.5—5.6           | 5—6       |
| 11 | Miemite          | $CaCO_3.MgCO_3$   | IV.            | 2.7—2.95          | 3.5—4     |
| 12 | Millerite        | NiS   | III.rh.        | 4.6—5.6           | 3—3.5     |
| 13 | Mimetisite       | See Mimetite.   |                |                   |           |
| 14 | Mimetite         | $3 [3 PbO.As_2O_5]. PbCl_2$   | III.           | 7—7.25            | 3.5       |
| 15 | Mineral Coal     | See Coal—Mineral.   |                |                   |           |
| 16 | — Oil            | $C_nH_{2n+2}$ series  |                | <1                |           |
| 17 | — Pitch          | See Asphaltum.  |                |                   |           |
| 18 | Minium           | $Pb_3O_4$   | Am             | 4.6               | 2—2.5     |
| 19 | Mirabilite       | $Na_2SO_4.H_2O$   | V.             | 1.4—1.5           | 1.5—2     |
| 20 | Mispickel        | $FeAsS$ or $FeAs_2.FeS_2$   | IV.            | 5.7—6.3           | 5.5—6     |
| 21 | Mixite           | $Cu_2O.As_2O_5.x H_2O$<br>with 13% $Bi_2O_3$                                  | IV.pris:       |                   |           |
| 22 | Mocha Stone      | Chalcedony with dendrites of $Fe_2O_3$ or ferruginous                         |                |                   |           |
| 23 | Molybdate, Lead  | See Wulfenite.  |                |                   |           |
| 24 | Molybdenite      | $MoS_2$   | III.           | 4.45—4.8          | 1—1.5     |
| 25 | Molybdic Ochre   | $MoO_3$   | IV             | 4.5               | 1—2       |
| 26 | Molybdiite       | See Molybdic Ochre.   |                |                   |           |
| 27 | Monazite         | $[Ce,La,Di]PO_4$ contg. Th  | V.             | 4.9—5.25          | 5—5.5     |
| 28 | Montmorillonite  | $Al_2O_3.SiO_2$ aq  |                |                   | Soft      |
| 29 | Monticellite     | $2 [Ca,Mg]O.SiO_2$  | IV.            | 3.3—3.6           | 6—7       |
| 30 | Moonstone        | Opalescent or pearly  | variety of     | Adularia.         |           |
| 31 | Morenosite       | $NiSO_4.7 H_2O$   |                |                   | 4—4.5     |
| 32 | Mosandrite       | $3 [CaO.(SiO_2, TiO_2)]$<br>$(Ce,La,Di)_2O_3$<br>$(SiO_2, TiO_2)_2$           | V.             | 2.9—3.03          | 4         |
| 33 | Moss Agate       | See Mocha Stone.  |                |                   |           |
| 34 | Mountain Cork    | Asbestos (q.v.). (Has elasticity of cork.)                                    |                |                   |           |

| Lustre.      | Colour.                           | Streak.           | Fracture.                 | Fusibility.  | Solubility.                                       |    |
|--------------|-----------------------------------|-------------------|---------------------------|--|---|----|
| Py.          | Y., G., Bl.                       |                   | oP.                       | 4  | Decomp.<br>$H_2SO_4$                              | 1  |
| Vit.         | Y., Br.                           |                   |                           | Inf.   | s. hot HCl  | 2  |
| Vit.         | C., W., Gr., Y.                   |                   | $\infty P$                | 2  | Gelatinous<br>$SiO_2$ with HCl                    | 3  |
|              |                                   |                   |                           |  |   | 4  |
|              | Gr. Bl.                           | Bl.               | Conch.,<br>uneven         | Sublimes   | s. $HNO_3$ +<br>HCl                               | 5  |
| Met. ad.     | Iron Bl.                          | Dark<br>cherry R. | Conch.,<br>uneven         | E. fus.  | s. $HNO_3$ with<br>sepn. of S<br>and $Sb_2O_3$    | 6  |
| Muscovite is | common Mic a:                     |                   |                           |  |   | 7  |
| Vit. py.     | C., W., Y.,<br>P., G.             |                   | oP, $\infty P$            | 5  | Ins.  | 8  |
| Greasy vit.  | Y., R., Br.                       |                   | Conch.,<br>uneven         |  | Decom. $H_2SO_4$<br>with sepn. of<br>white powder | 9  |
| Vit. py.     | Y. Br.                            | Y. Br.            | Fibrous                   | Inf.   | s. hot HCl  | 10 |
| Met.         | Brass Y.—<br>bronze Y.            | Bright            | Brittle                   | E. fus.  | s. $HNO_3$  | 11 |
|              |                                   |                   |                           |  |   | 12 |
| Res.         | Pale Y., Br. or<br>W.             | W.                | Conch.                    | $As_2O_3$ , and<br>$PbCl_2$ ,<br>volatilise<br>E. fus. | s. $HNO_3$ and<br>KOH                             | 13 |
|              |                                   |                   |                           |  |   | 14 |
|              | C. or pale Y.                     |                   |                           | Burn   |   | 15 |
| Dull         | R., Y.                            | Or. —             | Even, conch,<br>or earthy | 1  | Decomp. HCl<br>with sepn. of<br>$PbCl_2$          | 16 |
| Vit.         | C.                                |                   | $\infty P$                | E. fus.  | s. $H_2O$   | 17 |
| Met. shining | Silver W.—<br>steel Gr.           | Dark<br>Gr. Bl.   | Brittle                   | E. fus.  | s. $HNO_3$ with<br>sepn. of S and<br>$As_2O_3$    | 18 |
|              | Emerald—B. G                      |                   |                           |  |   | 19 |
| chlorite.    |                                   |                   |                           |  |   | 20 |
| Met.         | W., Gr.                           | Gr. G.<br>shining | oP.                       | Inf.   | s. $HNO_3$ with<br>sepn. of<br>$H_2MoO_4$ aq      | 21 |
| Sy.          | W. Y.                             | Y.                | oP.                       | E. fus.  | E. s. HCl   | 22 |
| Greasy       | Br., R., Y.                       | ?                 | oP.                       | D. fus.  | s. HCl, gives<br>white ppt.                       | 23 |
|              | Rose R.—W. or B.                  |                   | Earthy                    |  |   | 24 |
| Vit.         | Bottle G.                         |                   |                           | Inf.   | Gelatinous<br>$SiO_2$ with HCl                    | 25 |
|              |                                   |                   |                           |  |   | 26 |
| Greasy, vit. | Apple G.<br>R. Br., G.,<br>Y. Br. | Pale G.<br>Y.     | $\infty P$                | Fus.   | s. HCl with<br>sepn. of $SiO_2$                   | 27 |
|              |                                   |                   |                           |  |   | 28 |
|              | W. or Gr. W.                      |                   |                           |  |   | 29 |
|              |                                   |                   |                           |  |   | 30 |
|              |                                   |                   |                           |  |   | 31 |
|              |                                   |                   |                           |  |   | 32 |
|              |                                   |                   |                           |  |   | 33 |
|              |                                   |                   |                           |  |   | 34 |



| Name.               | Composition.   | Cryst. System.    | Specific Gravity. | Hardness. |
|---------------------|--|-------------------|-------------------|-----------|
| 1 Mountain Leather  | Asbestos (q.v.). (Thin   | tough she         | ets, somew        | hat like  |
| 2 - Tallow          | See Hatchettine.   |                   |                   |           |
| 3 Muller's glass    | See Hyalite.   |                   |                   |           |
| 4 Mundic            | Iron-pyrites (q.v.).   | Miners            | name for          | pyrites.  |
| 5 Muriacite         | See Anhydrite.   |                   |                   |           |
| 6 Muscovite         | $2\text{H}_2\text{O}.\text{K}_2\text{O}.3\text{Al}_2\text{O}_3.$<br>$6\text{SiO}_2$            | V                 | 2.7—3.1           | 2—2.5     |
| 7 Muscovy glass     | See Muscovite.   |                   |                   |           |
| 8 Nadorite          | $\text{PbO}.\text{SbOCl}$  | IV.               | 7—7.1             | 3         |
| 9 Nagyagite         | $10\text{PbS}.\text{Sb}_2\text{S}_3.2\text{AuTe}_2$<br>or $2\text{AuS}$                        | IV.               | 7.085             | 1—1.5     |
| 10 Nakrite          | $\text{Al}_2\text{O}_3.2\text{SiO}_2.\text{H}_2\text{O}$                                       | V.<br>crystalline | 2.63              | 1         |
| 11 Naphtha          | Oil of $\text{C}_n\text{H}_{2n+2}$ series  |                   | <1                |           |
| 12 Natrocalcite     | See Gaylussite.  |                   |                   |           |
| 13 Natrolite        | $\text{Na}_2\text{O}.\text{Al}_2\text{O}_3.3\text{SiO}_2.$<br>$2\text{H}_2\text{O}$            | IV.               | 2.24—2.25         | 5—5.5     |
| 14 Natron           | $\text{Na}_2\text{CO}_3.10\text{H}_2\text{O}$  | V.                | 1.42              | 1—1.5     |
| 15 Naumannite       | $(\text{Ag}, \text{Pb})\text{Se}$  | I.                | 8                 | 2—2.5     |
| 16 Needle Ore       | See Aikenite.  |                   |                   |           |
| 17 Nematite         | Brucite (q.v.).  |                   |                   |           |
| 18 Neocianite       | $\text{CuO}.\text{SiO}_2$  | V.                |                   |           |
| 19 Neolite          | $(\text{Mg}, \text{Fe})\text{O}.\text{Al}_2\text{O}_3.$<br>$x\text{SiO}_2.n\text{H}_2\text{O}$ | Crystalline       | 2.8               | 1         |
| 20 Neotype          | See Alstonite.   | III.              | 2.82              |           |
| 21 Nepheline        | $3(\text{Na}, \text{K})\text{O}.4\text{Al}_2\text{O}_3.$<br>$9\text{SiO}_2$                    | III.              | 2.55—2.62         | 5.5—6     |
| 22 Nephrite         | See Jade.  |                   |                   |           |
| 23 Niccolite        | $\text{NiAs}$  | III.              | 7.3—7.6           | 5—5.5     |
| 24 Nickel gymnite   | See Genthite.  |                   |                   |           |
| 25 - pyrites        | See Millerite.   |                   |                   |           |
| 26 - stibine        | See Ullmannite.  |                   |                   |           |
| 27 - vitriol        | See Morenosite.  |                   |                   |           |
| 28 Niobite          | $(\text{Fe}, \text{Mn})\text{O}.\text{(Nb, Ta)}_2\text{O}_5$                                   | IV.               | 5.4—6.5           | 5—6       |
| 29 Nitrate, Calcium | $\text{Ca}(\text{NO}_3)_2$   | IV. ?             |                   |           |
| 30 - Potassium      | $\text{KNO}_3$   | IV.               | 1.97              | 2         |
| 31 - Sodium         | $\text{NaNO}_3$ (deliquescent)   | III.rh.           | 2.09—2.29         | 1.5—2     |
| 32 Nitratine        | See Nitrate, Sodium.   |                   |                   |           |
| 33 Nitre            | See Nitrate, Potassium.  |                   |                   |           |
| 34 Nitrobarite      | $\text{Ba}(\text{NO}_3)_2$   |                   |                   | 1.5—2.5   |
| 35 Nitrocalcite     | See Nitrate, Calcium.  |                   |                   |           |
| 36 Nitromagnesite   | $\text{Mg}(\text{NO}_3)_2$   | Am.               | 2.3—2.7           | 1—2       |
| 37 Noëan            | $2\text{Na}_2\text{O}.\text{Al}_2\text{O}_3.3\text{SiO}_2.$<br>$+\text{Na}_2\text{SO}_4$       | I.                | 2.25—2.6          | 5.5—6     |
| 38 Nouméite         | See Garnierite.  |                   |                   |           |
| 39 Ochre, Brown     | See Limonite.  |                   |                   |           |
| 40 - Red            | See Hematite, Red.   |                   |                   |           |
| 41 - Yellow         | See Limonite.  |                   |                   |           |
| 42 Octahedrite      | See Anatase.   |                   |                   |           |
| 43 Odontolite       | See Bone Turquoise.  |                   |                   |           |
| 44 Oerstedtite      | Altered Zirkon with<br>$\text{H}_2\text{O}$ and $\text{TiO}_2$                                 |                   |                   |           |



| Lustre.                   | Colour.                       | Streak.            | Fracture.                               | Fusibility.        | Solubility.                                 |  |
|---------------------------|-------------------------------|--------------------|---|--------------------|---|--|
| Kid-leather.)             |                               |                    |   |                    |   | 1<br>2<br>3<br>4<br>5<br>6   |
| Py.                       | W., Bl., Br.,<br>Y., G., Gr.  | C.                 | Flexible,<br>elastic<br>and tough       | D. fus.            | Decomp. hot<br>$H_2SO_4$                    | 7<br>8<br>9  |
| Greasy-ad.<br>Met.        | Y., Br.<br>Bl.Gr.             | ?<br>Bl.Gr.        | $\infty P \infty$<br>$\infty P \infty$  | Fus.<br>E. fus.    | s. HCl<br>s. $HNO_3$ with<br>sepn. of Au    | 10<br>11<br>12   |
| Py.                       | W.Gr.                         |                    | oP.                                     | Inf.               | Decomp. HCl                                 | 13<br>14<br>15<br>16<br>17<br>18<br>19   |
| Vit.                      | W., Y., Gr.R.                 |                    | Brittle                                 | E. fus.            | Decomp. HCl                                 | 20<br>21<br>22<br>23<br>24<br>25<br>26<br>27<br>28   |
| Vit. or<br>earthy<br>Met. | W., Y., Gr.<br>Iron Bl.       | C.<br>Gr.Bl.       |   | E. fus.<br>E. fus. | s. $H_2O$<br>s. $HNO_3$                     | 29<br>30<br>31<br>32<br>33<br>34<br>35<br>36<br>37<br>38<br>39<br>40<br>41<br>42<br>43<br>44 |
| Dull<br>Vit.              | Bright B.<br>W., Gr., P., Y   | Pale B.<br>Shining | Fibrous<br>Flaky,<br>fibrous,<br>earthy |                    |   |  |
| Vit.—<br>greasy           | W., Gr., Y.,<br>G., B.R.      |                    | Sub-conch.                              | Fus.               | Gel. $SiO_2$ with<br>ac.                    |  |
| Met.                      | Pale copper R                 | Pale<br>Br.Bl.     | Brittle                                 | Fus.               | s. $HNO_3$ + HCl                            |  |
| Sub-met.ad.               | Iron Bl.,<br>Br.Bl.           | Bl.Br.,<br>R.      | Brittle                                 | Inf.               | Ins.  |  |
| Vit.<br>Vit.              | C., W.<br>W., Gr., Br.        | C.<br>C.           | Conch.<br>Conch.                        | E. fus.<br>E. fus. | s. $H_2O$<br>s. $H_2O$                      |  |
|                           | W., C., Y.                    | C.                 |   |                    | s. $H_2O$                                   |  |
| Deliquescent<br>Vit.      | W.<br>Gr., W., G.,<br>B., Bl. | W.<br>W.           | Earthy<br>$coO$                         | E. fus.<br>Fus.    | s. $H_2O$<br>Gelatinous<br>$SiO_2$ with HCl |  |
| Ad.                       | R.Br.                         |                    |   | Inf.               |   |  |

| Name. |              | Composition.                                       | Cryst. System. | Specific Gravity. | Hardness. |
|-------|--------------|--|----------------|-------------------|-----------|
| 1     | Ohgoclase    | $Ab_2An_1—Ab_2An_1$ .*<br>Mostly $Ab_2An_1$        | VI.            | 2.58—2.7          | 6         |
| 2     | Olivenite    | $4 CuO.As_2O_3$                                    | IV.            | 4.13—4.38         | 3         |
| 3     | Olivine      | See Chrysolite.                                    |                |                   |           |
| 4     | Onofrite     | Hg(S,Se)   | Am.            | 7.62              |           |
| 5     | Onyx         | Chalcedony (q.v.). [Fla                            | t-banded v     | ariety.]          |           |
| 6     | Oölite       | Compact $CaCO_3$ . (Ro                             | und concre     | tional gra        | ins, size |
| 7     | Opal         | $SiO_2$ compact, reni-<br>form or stalactitic      | Am.            | 2.21              | 5.5—6.5   |
| 8     | Opal Jasper  | $SiO_2$ . (Resembles jas                           | per but is     | not so hard.)     |           |
| 9     | Ophiolite    | Serpentine with lime-<br>stone                     |                |                   |           |
| 10    | Orangite     | $ThSiO_4$ with $CaO$ .<br>(Fe,Mn) $_2O_3$ , $UO_3$ | Am.            | 1.9—2.3           | 5.5—6.5   |
| 11    | Orpiment     | $As_2S_3$  | IV.            | 3.4—3.5           | 1.5—2     |
| 12    | Orthite      | (Al,Ce,Fe) $_2$ (AlOH)<br>$Ca_2Si_3O_{12}$         | V.             | 3—4               | 5.5—6     |
| 13    | Orthoclase   | $K_2O.Al_2O_3.6 SiO_2$                             | V.             | 2.39—2.62         | 6         |
| 14    | Osteolite    | Impure Apatite (q.v.)                              |                |                   |           |
| 15    | Ostranite    | See Zirkon.  |                |                   |           |
| 16    | Ouvarovite   | See Garnet, Lime-<br>Chrome.                       |                |                   |           |
| 17    | Ozokerite    | As for Hatchettine                                 | Am             | 1.2               | 0.5—1     |
| 18    | Pachnolite   | $NaF.CaF_2.AlF_3.H_2O$                             | V.             | 2.15—2.3          | 2.5—3     |
| 19    | Pagodite     | See Pinite.  |                |                   |           |
| 20    | Palladium    | $Pd(Pt, Ir)$                                       | I.             | 11.3—12.2         | 4.5—5     |
| 21    | Pandermite   | $3 CaO.4 BO_3.6 H_2O$                              | Am             | 2.26—2.48         | 3         |
| 22    | Paragonite   | Like Muscovite (q.v.)                              | Am.            | 2.75—2.9          |           |
| 23    | Paranthine   | See Scapolite.                                     |                |                   |           |
| 24    | Pargasite    | A pyroxene   |                | 3.11              |           |
| 25    | Parisite     | (CeF)(CaF) $_2$ CeCO $_3$ ,<br>with La and Di      | III.           | 4.35              | 4—5       |
| 26    | Pattersonite | See Thuringite.                                    |                |                   |           |
| 27    | Pearl Sinter | $SiO_2$  |                |                   |           |
| 28    | — Spar       | Dolomite   | III.rh.        |                   |           |
| 29    | Pectolite    | $4 CaO.Na_2O.H_2O.$<br>$6 SiO_2$                   | V.             | 2.86—2.88         | 5         |
| 30    | Peganite     | See Variscite                                      |                |                   |           |
| 31    | Pegmatolite  | Orthoclase (q.v.)                                  |                |                   |           |
| 32    | Pelagite     | $xMnO_2.yFe_2O_3.zH_2O$                            | Am.            |                   |           |
| 33    | Pencil-stone | See Pyrophyllite.                                  |                |                   |           |
| 34    | Pennine      | $4 H_2O.(Al,Fe)_2O_3.5$<br>(Mg,Fe) $O.3 SiO_2$     | III.rh.        | 2.6—2.75          | 2—2.5     |
| 35    | Penninite    | See Pennine.                                       |                |                   |           |
| 6     | Periclase    | MgO  | I.             | 3.674             | 6         |
| 7     | Pericline    | See Albite.  |                |                   |           |
| 8     | Peridot      | See Chrysolite.                                    |                |                   |           |
| 9     | Peristerite  | Albite with dissemina                              | ted grains     | of quartz.        |           |
| 9     | Perowskite   | $CaO.TiO_2$  | I.             | 3.95—4.0          | 5.5—6     |
| 11    | Petalite     | $Al_2O_3.Li_2O.8 SiO_2$                            | V.             | 2.4—2.5           | 6—6.5     |

\*Ab = Albite, An = Anorthite.

| Lustre.          | Colour.                                 | Streak.          | Fracture.              | Fusibility.                       | Solubility.                                       |    |
|------------------|---|------------------|------------------------|-----------------------------------|---|----|
| Res.vit.py.      | Gr., G., Y., W                          | C.               | Conch.,<br>uneven      | Fus.                              | Ins. ac.  | 1  |
| Vit. ad.         | Olive G.—<br>wood Br.                   | Olive G.<br>—Br. | Brittle                | E. fus.                           | s. $\text{HNO}_3$                                 | 2  |
|                  |   |                  |                        |                                   |   | 3  |
| Met.             | Bl.Gr.                                  | Bl.Gr.           | Massive<br>†           |                                   |   | 4  |
| of fish spawn.)  |   |                  |                        |                                   |   | 5  |
| Sub-vit.         | Opalescent                              | C.               | Conch.                 | Inf.                              | Ins.  | 6  |
|                  |   |                  |                        |                                   |   | 7  |
| Res.             |   |                  |                        |                                   |   | 8  |
|                  | G. clouded,<br>marble                   |                  |                        |                                   |   | 9  |
| Greasy           | R.Y.                                    |                  | Conch.,<br>uneven      | Inf.                              | s. HF and hot<br>KOH                              | 10 |
| Py: res.<br>dull | Fine Y                                  | Y                | Sectile,<br>flexible   | $\text{As}_2\text{O}_3$<br>volat. |   | 11 |
| Vit. py.         | Gr., Br., Bl.                           | G.Gr., Br        | Conch.                 | Fus.                              | Sometimes ins.<br>in acids.                       | 12 |
| Vit. py.         | W., R.W., P.<br>C., Y., G.<br>W. earthy | Gr.W.            | Conch.,<br>splintery   | 5                                 | Decomp. HF  | 13 |
|                  |   |                  |                        |                                   |   | 14 |
|                  |   |                  |                        |                                   |   | 15 |
|                  |   |                  |                        |                                   |   | 16 |
| Wax.             | Dark Y. or Br                           | W.               |                        | 130-140° F                        |   | 17 |
| Vit.             | C., W., Y.,                             | C.               | Uneven                 | E. fus.                           |   | 18 |
|                  |   |                  |                        |                                   |   | 19 |
| Met.             | Steel Gr.—<br>silver W.                 | Gr.W.<br>shining | Malleable              | Inf. alone                        | s. $\text{HNO}_3$                                 | 20 |
| Dull             | W.Gr.                                   | W.               |                        |                                   |   | 21 |
| Py.              | W., G., Y.                              |                  | Sectile                | Inf.                              |   | 22 |
|                  |   |                  |                        |                                   |   | 23 |
| Bright vit.      |   |                  |                        |                                   |   | 24 |
| Sy., py.         | Y.Br.                                   | Y.W.             | oP.                    | Inf.                              | D.s. HCl  | 25 |
|                  |   |                  |                        |                                   |   | 26 |
| Py.              |   |                  |                        |                                   |   | 27 |
| Py.              | (Crystals have                          | curved           | faces.)                |                                   |   | 28 |
| Vit. py          | W.Gr.                                   |                  | $\infty P \infty$ , oP | 2                                 | s. HCl with<br>sepn. of flocculent $\text{SiO}_2$ | 29 |
|                  |   |                  |                        |                                   |   | 30 |
|                  |   |                  |                        |                                   |   | 31 |
| Dull             | Br.BL                                   | Br.              | Concretion'y           | Inf.                              | s. HCl  | 32 |
|                  |   |                  |                        |                                   |   | 33 |
| Py.              | G., Y.—W.,<br>R.—V.                     |                  | Flexible               | D. fus.                           | Decomp.<br>$\text{H}_2\text{SO}_4$                | 34 |
|                  |   |                  |                        |                                   |   | 35 |
| Vit.             | Dark G.<br>W. semi-op.                  | G.W.             | $\infty O \infty$      | Inf.                              | D.s. HCl  | 36 |
|                  |   |                  |                        |                                   |   | 37 |
|                  |   |                  |                        |                                   |   | 38 |
|                  |   |                  |                        |                                   |   | 39 |
| Ad.              | Y., Br., Bl.                            | W., Gr.          | $\infty O \infty$      | Inf.                              | Decomp. hot<br>$\text{H}_2\text{SO}_4$            | 40 |
| Vit. py.         | C., W., Gr.,<br>P., G.W.                | W.               |                        | D. fus.                           | Decomp. HF  | 41 |

| Name. |                         | Composition.   | Cryst. System.       | Specific Gravity. | Hardness.   |
|-------|-------------------------|--|----------------------|-------------------|-------------|
| 1     | Petrified Wood          | SiO <sub>2</sub>   | (Silica replaces the | original          |             |
| 2     | Petroleum               | Mainly C <sub>n</sub> H <sub>2n+2</sub> series   | Liq.                 | .60—.85           | —           |
| 3     | Petzite                 | (Ag, Au) <sub>2</sub> Te   | I.                   | 8.7—9.4           | 2.5—3       |
| 4     | Phacolite               | See Chabazite.   |                      |                   |             |
| 5     | Pharmacolite            | 2 CaO.As <sub>2</sub> O <sub>5</sub> .5 H <sub>2</sub> O   | V                    | 2.6—2.7           | 2—2.5       |
| 6     | Pharmacosiderite        | 3 As <sub>2</sub> O <sub>5</sub> .Fe <sub>2</sub> O <sub>3</sub> .3 FeOH<br>.12 H <sub>2</sub> O   | I.                   | 3                 | 2.5         |
| 7     | Phenacite               | BeSiO <sub>4</sub>   | III.rh.              | 3                 | 7.5—8       |
| 8     | Phengite                | Muscovite (q.v.). (Contains more silica.)  |                      |                   |             |
| 9     | Philippite              | CuSO <sub>4</sub> .FeSO <sub>4</sub> .x H <sub>2</sub> O   |                      |                   |             |
| 10    | Phillipsite             | (Ca,Na <sub>2</sub> ,K <sub>2</sub> )O.Al <sub>2</sub> O <sub>3</sub> .<br>6 SiO <sub>2</sub> +6 H <sub>2</sub> O<br>(Ca,Na <sub>2</sub> ,K <sub>2</sub> )O.2 Al <sub>2</sub> O <sub>3</sub> .<br>4 SiO <sub>2</sub> +6 H <sub>2</sub> O | V.                   | 2.2—2.4           | 4—4.5       |
| 11    | Phlogopite              | 3 (K <sub>2</sub> ,H <sub>2</sub> )O.6 (Mg,Fe)<br>O.(Al <sub>2</sub> ,Fe <sub>2</sub> )O <sub>3</sub> .6 SiO <sub>2</sub>  | V.                   | 2.8—3.2           | 2—3         |
| 12    | Phoenicochroite         | PbCrO <sub>4</sub>   | II.                  | 5.75              |             |
| 13    | Phosgenite              | See Horn Lead.   |                      |                   |             |
| 14    | Phosphate,<br>Aluminium | See Wavellite.   |                      |                   |             |
| 15    | — Ammonium              | See Struvite.  |                      |                   |             |
| 16    | — Calcium               | See Apatite.   |                      |                   |             |
| 17    | — Cerium                | See Monazite.  |                      |                   |             |
| 18    | — Copper                | See Pseudomalachite  | and Libethenite.     |                   |             |
| 19    | — Iron                  | See Vivianite.   |                      |                   |             |
| 20    | — Lead                  | See Pyromorphite.  |                      |                   |             |
| 21    | — Manganese             | See Triphylite.  |                      |                   |             |
| 22    | — Uranium               | See Torbernite.  |                      |                   |             |
| 23    | — Yttrium               | See Monazite.  |                      |                   |             |
| 24    | Phosphocalcite          | See Pseudomalachite  |                      |                   |             |
| 25    | Phosphocerite           | See Rhabdophane.   |                      |                   |             |
| 26    | Phosphochalcite         | See Pseudomalachite.   |                      |                   | 4.5—5       |
| 27    | Phosphorite             | See Apatite.   |                      |                   |             |
| 28    | Phosphuranylite         | (U,Pb)O.P <sub>2</sub> O <sub>5</sub> . aq   | Am                   |                   |             |
| 29    | Phyllite                | See Chloritoid   |                      |                   |             |
| 30    | Physalite               | Al <sub>2</sub> O <sub>3</sub> .SiO <sub>2</sub>   | IV.                  | 3.4—3.65          | 8           |
| 31    | Pickeringite            | See Alum-Magnesia.   |                      |                   |             |
| 32    | Picotite                | MgO.Al <sub>2</sub> O <sub>3</sub> with Fe<br>and 7% CrO <sub>3</sub>  | I.                   | 4.08              | 8           |
| 33    | Picromerite             | (K <sub>2</sub> ,Mg)SO <sub>4</sub> . aq   | IV.                  |                   | 2—2.5       |
| 34    | Piedmontite             | H <sub>2</sub> O.4 CaO.<br>3(Al,Mn) <sub>2</sub> O <sub>3</sub> .6 SiO <sub>2</sub>  | V.                   | 3.4               | 6.5         |
| 35    | Pimelite                | Meerschaum contg. Ni   | Am                   | 2.2—2.8           | 2.5         |
| 36    | Pinite                  | 2 Al <sub>2</sub> O <sub>3</sub> .K <sub>2</sub> O.3 H <sub>2</sub> O.<br>5 SiO <sub>2</sub>   | Am.                  | 2.6—2.7           | 2.5—3.5     |
| 37    | Pisolite                | CaCO <sub>3</sub> . (Compact, rounded, concretionary grains, the   |                      |                   |             |
| 38    | Pistacite               | Epidote (q.v.)   |                      |                   |             |
| 39    | Pitchblende             | UO <sub>2</sub> U <sub>2</sub> O <sub>5</sub>  | I.                   | 6.4—9.7           | 5.5         |
| 40    | Pitticite               | See Scorodite.   |                      |                   |             |
| 41    | Plagioclase             | General Name for triclinic feldspars.  |                      |                   | See Albite, |

| Lustre.                           | Colour.                      | Streak.      | Fracture.              | Fusibility. | Solubility.   |    |
|-----------------------------------|------------------------------|--------------|------------------------|-------------|---|----|
| structure.)                       | C.                           |              |                        | Burns       |   | 1  |
| Met.                              | Gr., Gr.Bl.                  | Shining      | Conch.                 | E. fus.     | s. $\text{HNO}_3$   | 2  |
|                                   | C. lenticular crystals       |              |                        |             |   | 3  |
| Vit.—py.                          | C.W.                         |              | $\infty P \infty$      | E. fus.     | s. $\text{HNO}_3$   | 4  |
| Ad.                               | Dark G., Br., R.             | G.Br.        |                        |             |   | 5  |
| Vit.                              | C., Y., W., Gr.              |              | Conch.                 | Inf.        | Ins.  | 6  |
|                                   |                              |              |                        |             |   | 7  |
|                                   |                              |              |                        |             |   | 8  |
| Vit.                              | Azure B. C., Gr., W., Y., P. |              | $\infty P \infty$ , oP | Fus.        | s. HCl with sepn. of gelatinous $\text{SiO}_2$              | 9  |
|                                   |                              |              |                        |             |   | 10 |
| Py.                               | C., Y., R. Br., G., Bl.      |              | oP                     |             | Décomp. $\text{H}_2\text{SO}_4$                             | 11 |
|                                   | Dark R.                      | Brick R.     |                        |             |   | 12 |
|                                   |                              |              |                        |             |   | 13 |
|                                   |                              |              |                        |             |   | 14 |
|                                   |                              |              |                        |             |   | 15 |
|                                   |                              |              |                        |             |   | 16 |
|                                   |                              |              |                        |             |   | 17 |
|                                   |                              |              |                        |             |   | 18 |
|                                   |                              |              |                        |             |   | 19 |
|                                   |                              |              |                        |             |   | 20 |
|                                   |                              |              |                        |             |   | 21 |
|                                   |                              |              |                        |             |   | 22 |
|                                   |                              |              |                        |             |   | 23 |
|                                   |                              |              |                        |             |   | 24 |
|                                   |                              |              |                        |             |   | 25 |
|                                   |                              |              |                        |             |   | 26 |
|                                   | Emerald or Bl.G.             |              |                        |             |   | 27 |
| Dull                              | Lemon Y.                     | Y.           | Brittle                |             |   | 28 |
| Vit.                              | Nearly op. Y.W.              | Y.W.         | Conch.                 | Intumesces  | Ins.  | 29 |
|                                   |                              |              |                        |             |   | 30 |
| Vit.                              | Bl.                          | Bl.          | Conch.                 | Inf.        | Ins.  | 31 |
|                                   |                              |              |                        |             |   | 32 |
| Earthy                            | W.                           | W.           | Earthy                 | Fus.        | s. $\text{H}_2\text{O}$                                     | 33 |
| Vit.                              | R.Br., Bl.R., R.             | R.           | oP                     | E. fus.     | Gel. $\text{SiO}_2$ after heating to redness and adding HCl | 34 |
|                                   |                              |              |                        |             |   | 35 |
| Greasy Wax.                       | G. Gr.G., Br.R.              |              | Conch. Brittle         | Inf.        |   | 36 |
|                                   |                              |              |                        |             |   | 37 |
| size of a sm                      | all pea.)                    |              |                        |             |   | 38 |
|                                   | G.                           |              |                        |             |   | 39 |
| Sub-met. greasy, pitch-like, dull | Gr., Br., velvet Bl.         | Bl.Gr. or G. |                        | Inf.        | s. $\text{HNO}_3$   | 40 |
|                                   |                              |              |                        |             |   | 41 |
| Oligoclase,                       | Andesine, Labradorite,       | etc.         |                        |             |   |    |

|    | Name.              | Composition.  | Cryst. System. | Specific Gravity. | Hardness. |
|----|--------------------|---|----------------|-------------------|-----------|
| 1  | Plagionite         | 5 PbS.4 Sb <sub>2</sub> S <sub>3</sub>  | V.             | 5.4               | 2.5       |
| 2  | Plasna             | SiO <sub>2</sub> (chalcedony).  |                |                   |           |
| 3  | Plaster of Paris   | Dehydrated Gypsum.  |                |                   |           |
| 4  | Platiniridium      | Pt + Ir(Rh, Pd, Cu)   | I.             | 22—23             | 6—7       |
| 5  | Platinum           | Pt(Ir, Rh, Pd, Os, Cu)  | I.             | 17—18             | 4—4.5     |
| 6  | Pleonast           | (Mg, Fe)O.(Al, Fe) <sub>2</sub> O <sub>3</sub>  | I.             | 3.6—3.7           | 8         |
| 7  | Plessite           | See Gersdorffite.   |                |                   |           |
| 8  | Plumbago           | See Graphite.   |                |                   |           |
| 9  | Plumbogummite      | PbO.Al <sub>2</sub> O <sub>3</sub> . aq   | Globular       | 6.3—6.4           | 4—4.5     |
| 10 | Polianite          | MnO <sub>2</sub> . (See Pyrolusite.)  |                |                   |           |
| 11 | Pollucite (Pollux) | H <sub>2</sub> O.Al <sub>2</sub> O <sub>3</sub> .Cs <sub>2</sub> O.5 SiO <sub>2</sub>               | I.             | 2.868             | 6—7       |
| 12 | Polyargyrite       | 12 Ag <sub>2</sub> S.Sb <sub>2</sub> S <sub>3</sub>   | I.             | 6.2—6.5           | 2—2.5     |
| 13 | Polybasite         | 9 (Ag, Cu) <sub>2</sub> S.(Sb, As) <sub>2</sub> S <sub>3</sub>                                      | IV.            | 6.2—6.3           | 2—2.5     |
| 14 | Polydymite         | (Ni, Co) <sub>4</sub> S <sub>5</sub>  | I.             | 4.8               | 4.5       |
| 15 | Polyhalite         | 2 CaO.MgO.K <sub>2</sub> O.<br>4 SO <sub>3</sub> .2 H <sub>2</sub> O                                | V.             | 2.72—2.77         | 3—3.5     |
| 16 | Polycrase          | Similar to Euxenite (q.v.)  | IV.            | 4.7—5.1           | 5—6       |
| 17 | Polymignite        | 4(Ca, Ce, Fe)O.(Ti, Zr)O <sub>2</sub><br>CaO.Nb <sub>2</sub> O <sub>5</sub>                         | IV.            | 4.77—4.85         | 6—6.5     |
| 18 | Porcelain Jasper   | A baked clay.   |                |                   |           |
| 19 | Porpezite          | Au with 7—11% Pd  | I.             | 11—15             |           |
| 20 | Potash Mica        | See Muscovite.  |                |                   |           |
| 21 | Potstone           | 2 (CaO.SiO <sub>3</sub> ) + Al <sub>2</sub> O <sub>3</sub> .<br>SiO <sub>2</sub> + H <sub>2</sub> O |                |                   |           |
| 22 | Prase              | SiO <sub>2</sub> (quartz)   | III.rh.        | 2.5—2.8           | 7         |
| 23 | Praseolite         | Decomposed Cordierite   | IV.            | 2.75              | 3—4       |
| 24 | Prehnite           | H <sub>2</sub> O.2 CaO.Al <sub>2</sub> O <sub>3</sub> .<br>3 SiO <sub>2</sub>                       | IV.            | 2.8—2.95          | 6.5—7     |
| 25 | Priceite           | 3 CaO.4 BO <sub>3</sub> .6 H <sub>2</sub> O   | Am.            | 2.262             |           |
| 26 | Prochlorite        | Similar to Pennine and chlorite   | III.           | 2.75—3            | 2—2.5     |
| 27 | Proidonite         | SiF <sub>4</sub>  |                |                   |           |
| 28 | Prosopite          | Ca(F, OH) <sub>2</sub> .Al <sub>2</sub> (F, OH) <sub>4</sub>  | V.             | 2.8—2.9           | 4—5       |
| 29 | Proustite          | 3 Ag <sub>2</sub> S. + As <sub>2</sub> S <sub>3</sub>   | III.rh. h.     | 5.4—5.6           | 2—2.5     |
| 30 | Pseudobrookite     | 2 Fe <sub>2</sub> O <sub>3</sub> .3 TiO <sub>2</sub>  | IV.            | 4.9—5.0           | 6         |
| 31 | Pseudomalachite    | Cu <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> aq.   | V.             | 4—4.4             | 4.5—5     |
| 32 | Psilomelane        | MnO <sub>2</sub> + (Mn, Ba, K) <sub>2</sub> O.<br>+ xH <sub>2</sub> O                               | Am.            | 3.7—4.7           | 5—6       |
| 33 | Pucherite          | Bi <sub>2</sub> O <sub>3</sub> .V <sub>2</sub> O <sub>5</sub>                                       | IV.            | 6.25              | 6         |
| 34 | Purple Copper      | See Bornite.  |                |                   |           |
| 35 | Pyrargyrite        | 3 Ag <sub>2</sub> S.Sb <sub>2</sub> S <sub>3</sub>  | III.rh.        | 5.7—5.9           | 2—2.5     |
| 36 | Pyreneite          | See Garnet, Iron-lime.  |                | 3.64—4            |           |
| 37 | Pyrites, Arsenical | See Mispickel.  |                |                   |           |
| 38 | — Auriferous       | Iron pyrites contg. Au  |                |                   |           |

| Lustre.               | Colour.                                  | Streak.           | Fracture.                       | Fusibility.      | Solubility.  |    |
|-----------------------|--|-------------------|---------------------------------|------------------|--|----|
| Met.                  | Gr.                                      | Gr.               |                                 | E. fus.          | s. HCl with<br>sepn. of<br>PbCl <sub>2</sub>                                 | 1  |
|                       | TL.G. sprinkled<br>with W. & Y.<br>dots. |                   |                                 |                  |  | 2  |
| Met.                  | W., Gr.                                  | Gr.<br>shining    | Hackly                          | Inf.             | s. HNO <sub>3</sub> + HCl  | 3  |
| Met.                  | Gr.                                      | Gr.               | Hackly                          | Inf.             | s. HNO <sub>3</sub> + HCl  | 4  |
| Vit.                  | Gr., Bl.                                 | Dark Gr.          | Conch.                          | Inf.             | Ins.   | 5  |
|                       |  |                   |                                 |                  |  | 6  |
|                       |  |                   |                                 |                  |  | 7  |
|                       |  |                   |                                 |                  |  | 8  |
| Like gum-<br>arabic   | Y.Br., R.Br.                             | Light R.          | Earthy                          | Inf.             |  | 9  |
|                       |  |                   |                                 |                  |  | 10 |
| Vit.                  | W.                                       |                   | Conch.                          | D fus.           | Decomp. HCl  | 11 |
| Met.                  | Gr.Bl.                                   | Gr.Bl.            | Brittle                         | E. fus.          | Decom. HNO <sub>3</sub>  | 12 |
| Met.                  | Gr.Bl.                                   | Bl.               | Uneven                          | E. fus.          | Decom. HNO <sub>3</sub>  | 13 |
| Brilliant<br>met.     | Gr.                                      | Bl.Gr.            | ∞O∞                             | E. fus.          | s. HNO <sub>3</sub>  | 14 |
| Almost<br>greasy      | C., W., R.                               |                   | Fibrous                         | 3                | s. H <sub>2</sub> O  | 15 |
| Met.                  | Bl.                                      | Gr.Br.            | Conch.                          | Inf.             | s. H <sub>2</sub> SO <sub>4</sub>  | 16 |
| Nearly met.           | Bl.                                      | Bl.Br.            | Conch.                          | Inf.             | Decom. H <sub>2</sub> SO <sub>4</sub>  | 17 |
|                       | Gr.—R.                                   |                   | As for flint                    | Somewhat<br>fus. |  | 18 |
| Met.                  | Y.W.                                     | Shining           | V.malleable                     | Fus.             | s. Aqua-regia  | 19 |
|                       | Gr.G., Gr. G.,<br>or Br.Bl.              |                   | Can be<br>turned on<br>a lathe. |                  |  | 20 |
|                       |  |                   |                                 |                  |  | 21 |
| Vit.                  | Leek G.                                  |                   |                                 | Inf.             |  | 22 |
| Greasy                | G.                                       |                   |                                 | Fus.             |  | 23 |
| Vit.                  | G.                                       |                   | oP.                             | 2                | Gelatinous<br>SiO <sub>2</sub> with HCl                                      | 24 |
| Dull                  | W. chalky                                | W.                | Chalky                          | Fus.             | s. hot H <sub>2</sub> O  | 25 |
| Py.                   | G.—Bl.G.                                 | G.                | Not elastic                     | D. fus.          | Decom. H <sub>2</sub> SO <sub>4</sub>  | 26 |
|                       |  |                   |                                 |                  |  | 27 |
| Vit.                  | W., Gr., C.                              |                   | Conch.                          |                  |  | 28 |
| Splendent             | Light<br>cochineal R.                    | Cochi-<br>neal R. | Conch.                          | E. fus.          | s. HNO <sub>3</sub> with<br>sepn. of S<br>and As <sub>2</sub> O <sub>3</sub> | 29 |
| Vit.                  | R.Br., Bl.                               | Br.               | ∞P∞                             | Inf.             | s. H <sub>2</sub> SO <sub>4</sub>  | 30 |
| Greasy                | Emerald or<br>Bl.G.                      | G.                | Uneven,<br>brittle              | E. fus.          | s. HNO <sub>3</sub>  | 31 |
| Dull                  | Bl.Gr.                                   | Br.Bl.<br>shining | Even,<br>conch.                 | Inf.             | s. HCl   | 32 |
| Vit. ad.              | R., Br.                                  |                   | oP                              | E. fus.          | s. HCl   | 33 |
|                       |  |                   |                                 |                  |  | 34 |
| Met. ad.<br>splendent | Bl.—dark<br>cochineal R.                 | Cochi-<br>neal R. | R.                              | 1.               | s. HNO <sub>3</sub> with<br>sepn. of S<br>and Sb <sub>2</sub> O <sub>3</sub> | 35 |
|                       | Bl.                                      |                   |                                 |                  |  | 36 |
|                       |  |                   |                                 |                  |  | 37 |
|                       |  |                   |                                 |                  |  | 38 |



| Name. |                    | Composition.  | Cryst. System.             | Specific Gravity. | Hardness. |
|-------|--------------------|---|----------------------------|-------------------|-----------|
| 1     | Pyrites, Capillary | See Millerite.  |                            |                   |           |
| 2     | — Cobalt           | See Smaltine.   |                            |                   |           |
| 3     | — Coxcomb          | See Marcasite.  |                            |                   |           |
| 4     | — Copper           | $\text{CuFeS}_2$  | II.                        | 4.15—4.3          | 3.5—4     |
| 5     | — Iron             | $\text{FeS}_2$  | I.                         | 4.8—5.1           | 6—6.5     |
| 6     | — Magnetic         | See Pyrrhotine.   |                            |                   |           |
| 7     | — Radiated         | See Marcasite.  |                            |                   |           |
| 8     | — White Iron       | See Marcasite.  |                            |                   |           |
| 9     | Pyrochlore         | $(\text{Ca, Fe, Ce})\text{O} \cdot (\text{Nb, Ti, Th})\text{O}_2 \cdot \text{H}_2\text{O}$  | I.                         | 4.2—4.5           | 5—5.5     |
| 10    | Pyrochroite        | $\text{Mn}(\text{OH})_2$  | Am.                        |                   |           |
| 11    | Pyrolusite         | $\text{MnO}_2$  | Am.                        | 4.8—5             | 2—2.5     |
| 12    | Pyromorphite       | $3 (3 \text{ PbO} \cdot \text{P}_2\text{O}_5) + \text{PbCl}_2$  | III.                       | 6.5—7.1           | 3.5—4     |
| 13    | Pyrope             | See Garnet, Magnesia.   | -Alumina.                  |                   |           |
| 14    | Pyrophyllite       | $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O} \cdot 4 \text{ SiO}_2$  | IV.                        | 2.75—2.92         | 1—2       |
| 15    | Pyrostilbite       | See Kermesite.  |                            |                   |           |
| 16    | Pyrostilpnite      | Impure $\text{Ag}_2\text{S}$  | V.                         |                   | 2—2.5     |
| 17    | Pyroxene           | $\text{CaO} \cdot \text{MgO} \cdot 2 \text{ SiO}_2$ with $(\text{Mg, Fe})\text{O} \cdot (\text{Al, Fe})_2\text{O}_3 \cdot \text{SiO}_2$ | (See Augite, Wollastonite, |                   |           |
| 18    | Pyrrhosiderite     | See Göthite.  |                            |                   |           |
| 19    | Pyrrhotine         | $\text{FeS}$  | III.                       | 4.4—4.65          | 3.5—4.5   |
| 20    | Quartz             | $\text{SiO}_2$  | III. trap.                 | 2.5—2.8           | 7         |
| 21    | Quicksilver        | See Mercury.  |                            |                   |           |
| 22    | Raddle             | Red Hematite (q.v.)   |                            |                   |           |
| 23    | Ralstonite         | $3 \text{ Al}(\text{OH, F})_3 \cdot (\text{Na}_2, \text{Mg})\text{F}_2 \cdot 2 \text{ H}_2\text{O}$                                     | I.                         | 2.56              | 4.5       |
| 24    | Ratholite          | See Pectolite.  |                            |                   |           |
| 25    | Realgar            | $\text{As}_2\text{S}_2$   | V.                         | 3.4—3.6           | 1.5—2     |
| 26    | Red Antimony       | See Kermesite.  |                            |                   |           |
| 27    | — Chalk            | See Hematite, Red.  |                            |                   |           |
| 28    | — Copper Ore       | See Cuprite.  |                            |                   |           |
| 29    | — Hematite         | See Hematite, Red.  |                            |                   |           |
| 30    | — Lead             | $\text{Pb}_3\text{O}_4$   | Am.                        | 4.6               |           |
| 31    | — Ochre            | See Hematite, Red.  |                            |                   |           |
| 32    | — Silver Ore       | See Pyrargyrite.  |                            |                   |           |
| 33    | — Zinc Ore         | —Zincite.   |                            |                   |           |
| 34    | Reddle             | See Raddle.   |                            |                   |           |
| 35    | Reddingite         | $3 (\text{Mn, Fe})\text{O} \cdot \text{P}_2\text{O}_5 \cdot \text{aq}$  | Am.                        |                   |           |
| 36    | Redruthite         | $\text{Cu}_2\text{S}$   | IV.                        | 5.5—5.8           | 2.5—3     |
| 37    | Reinite            | $\text{FeWO}_4$   | II. pyr. h.                | 6.64              | 4         |
| 38    | Remolinite         | See Atacamite.  |                            |                   |           |
| 39    | Rennselaerite      | Talc (q.v.).  |                            |                   | 3—4       |
| 40    | Retinite           | $\text{C}_{12}\text{H}_{18}\text{O}$  | Am.                        | 1.05—1.15         | 1.5—2     |
| 41    | Retzbanite         | $\text{Pb}(\text{Bi, S})$   | I.                         |                   |           |



| Lustre.     | Colour.                          | Streak.           | Fracture.                     | Fusibility.   | Solubility.                          |    |
|-------------|----------------------------------|-------------------|-------------------------------|---|--------------------------------------|----|
|             |                                  |                   |                               |   |                                      | 1  |
|             |                                  |                   |                               |   |                                      | 2  |
|             |                                  |                   |                               |   |                                      | 3  |
| Met.        | Brass Y.                         | G.Bl. unmet.      | Brittle                       | Fus.  | s. $\text{HNO}_3$ with sepn. of S    | 4  |
| Met.        | Brass Y.                         | G.Bl., Br.Bl.     | Conch., uneven, brittle       | Fus.  |                                      | 5  |
|             |                                  |                   |                               |   |                                      | 6  |
|             |                                  |                   |                               |   |                                      | 7  |
|             |                                  |                   |                               |   |                                      | 8  |
| Vit. greasy | R.Br., Bl.Br.                    | Br.               | Conch.                        | D. fus.   | Decom. $\text{H}_2\text{SO}_4$       | 9  |
|             | W.                               | W.                |                               |   |                                      | 10 |
| Met.        | Bl.                              | Bl.               | Brittle                       | Inf.  | s. $\text{HCl}$                      | 11 |
| Res.        | G., Y., B.                       | W. or Y.W.        | Sub-conch. or uneven, brittle | E. fus.   | s. $\text{HNO}_3$                    | 12 |
|             |                                  |                   |                               |   |                                      | 13 |
| Py.         | W., Gr.W., G., Bl.               |                   | oP                            | 8   | Decom. $\text{H}_2\text{SO}_4$       | 14 |
|             |                                  |                   |                               |   |                                      | 15 |
| Spodumene.) | Fire. R.                         | R.                |                               |   |                                      | 16 |
|             |                                  |                   |                               |   |                                      | 17 |
|             |                                  |                   |                               |   |                                      | 18 |
| Met.        | R., Br., bronze or copper        | Gr.Bl.            | Uneven brittle                | E. fus.   | s. $\text{HCl}$ with sepn. of S      | 19 |
| Vit.        | C., Gr., Y., Br., B., G., P., V. |                   | Conch. splintery              | Inf.  | D.s. $\text{KOH}$ and s. $\text{HF}$ | 20 |
|             |                                  |                   |                               |   |                                      | 21 |
| Dull        |                                  |                   | Earthy                        |   |                                      | 22 |
|             |                                  |                   |                               |   |                                      | 23 |
|             |                                  |                   |                               |   |                                      | 24 |
| Res.        | R., Orange                       | R., Orange        | Conch.                        | Burns, giving off $\text{As}_2\text{O}_3$ and $\text{SO}_3$ | s. $\text{HNO}_3$ with sepn. of S    | 25 |
|             |                                  |                   |                               |   |                                      | 26 |
|             |                                  |                   | Compact, fine                 |   |                                      | 27 |
|             |                                  |                   |                               |   |                                      | 28 |
|             |                                  |                   |                               |   |                                      | 29 |
| Dull        | Bright R.                        | R.                | Earthy Soft, earthy           | E. fus.   | s. $\text{HNO}_3$                    | 30 |
|             |                                  |                   |                               |   |                                      | 31 |
|             |                                  |                   |                               |   |                                      | 32 |
|             |                                  |                   |                               |   |                                      | 33 |
|             |                                  |                   |                               |   |                                      | 34 |
|             |                                  |                   |                               |   |                                      | 35 |
| Met.        | Rose P. Blackish-lead Gr.        | P.W. Lead Gr.-Bl. | Brittle                       | E. fus.   | s. $\text{HNO}_3$ with sepn. of S    | 36 |
| Vit.        | Bl., Br.                         | Br.               |                               | Fus.  | Decomp. $\text{HCl}$                 | 37 |
|             | W., Y., Bl.                      |                   |                               |   |                                      | 38 |
|             |                                  |                   |                               |   |                                      | 39 |
| Greasy Met. | Y., Br. Steel Gr.                | W.Y. Gr.          | Conch.                        | 250° burns  |                                      | 40 |
|             |                                  |                   |                               |   |                                      | 41 |

| Name.                 | Composition.   | Cryst. System. | Specific Gravity. | Hardness. |
|-----------------------|--|----------------|-------------------|-----------|
| 1 Rhabdophane         | (Ce,La,Di) <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub>  |                |                   |           |
| 2 Rhodium Gold        | (Rh,Au).Rh=30-45%  | I.             | 15.5-16.8         |           |
| 3 Rhodizite           | 3 CaO.4 B <sub>2</sub> O <sub>3</sub> . $\frac{1}{2}$ CaCl <sub>2</sub>  | I.             | 2.97-3.5          | 7         |
| 4 Rhodochrosite       | MnCO <sub>3</sub>  | III.rh.        | 3.45-3.6          | 3.5-4.5   |
| 5 Rhodonite           | MnO.SiO <sub>2</sub>   | VI.            | 3.4-3.6           | 5.5-6.5   |
| 6 Rhoetizite          | See Kyanite.   |                |                   |           |
| 7 Rhomb Spar          | Dolomite in rhombs   | III.rh.        |                   |           |
| 8 Richellite          | (Fe,Ca) <sub>2</sub> [Fe <sub>2</sub> (PO <sub>4</sub> ) <sub>2</sub> ]  |                | 2                 |           |
| 9 Riebeckite          | Na <sub>2</sub> O.Fe <sub>2</sub> O <sub>3</sub> .4 SiO <sub>2</sub> .<br>4 FeO.4 SiO <sub>2</sub>                             | V.             | 3.3-3.4           | ?         |
| 10 Rinkite            | 3NaF.4CaO.6(Si,Ti)O <sub>2</sub> .<br>Ce <sub>2</sub> O <sub>3</sub>   | V.             | 3.46              | 5         |
| 11 Ripidolite         | 4 H <sub>2</sub> O.(Al,Cr) <sub>2</sub> O <sub>3</sub> .<br>5(Mg,Fe)O.3 SiO <sub>2</sub>                                       | V.             | 2.6-2.75          | 2-2.5     |
| 12 Rivotite           | Cu(CO <sub>3</sub> ,Sb <sub>2</sub> O <sub>4</sub> )   |                |                   |           |
| 13 Rock Crystal       | See Quartz.  |                |                   |           |
| 14 - Meal             | CaCO <sub>3</sub>  | Am.            | (Deposited from   |           |
| 15 - Milk             | Fine quality of Rock Meal.   |                |                   |           |
| 16 - Salt             | NaCl   | I.             | 2.1-2.2           | 2-2.5     |
| 17 - Tallow           | See Hatchettine.   |                |                   |           |
| 18 Romeite            | CaO.Sb <sub>2</sub> O <sub>3</sub>   | II.            |                   |           |
| 19 Roscoelite         | Vanadium-mica  |                |                   |           |
| 20 Roselite           | 3 (Ca,Co,Mg)O.As <sub>2</sub> O <sub>3</sub> .<br>2 H <sub>2</sub> O   | VI.            | 3.46              | 3.5       |
| 21 Rosellane (Rosite) | Decomposed Anorthite   |                | 2.72              |           |
| 22 Rose Quartz        | SiO <sub>2</sub>   | III. t p.      | 2.5-2.8           | 7         |
| 23 Rothoffite         | 6 (Mn,Ca)O.3 SiO <sub>2</sub> +<br>2 Fe <sub>2</sub> O <sub>3</sub> .3 SiO <sub>2</sub>  | I.             | 3.6-4             | 6.5-7.5   |
| 24 Röttisite          | 2 NiO.3 SiO <sub>2</sub> .2 H <sub>2</sub> O   | Am             | 2.3-2.4           | 2-2.5     |
| 25 Rowlandite         | Y silicate contg.<br>Ce,La,Th  |                | 4.51              | 6         |
| 26 Rubellite          | Tourmaline (q.v.)  |                |                   |           |
| 27 Rubicelle          | Spinel (q.v.)  |                |                   |           |
| 28 Ruby, Almandine    | Spinel (q.v.)  |                |                   |           |
| 29 - Balas            | Spinel (q.v.)  |                |                   |           |
| 30 - Oriental         | Al <sub>2</sub> O <sub>3</sub>   | III.rh.        | 3.90-4.16         | 9         |
| 31 - Silver           | See Pyrargyrite.   |                |                   |           |
| 32 - Spinel           | Spinel (q.v.)  |                |                   |           |
| 33 Rutherfordite      | (Ce,La,Di) phosphate.<br>Uncertain   | ?              |                   |           |
| 34 Rutile             | TiO <sub>2</sub>   | II.            | 4.18-4.22         | 6-6.5     |
| 35 Safflorite         | (Fe,Co)As <sub>2</sub>   | IV.            |                   | 3-3.5     |
| 36 Sagenite           | SiO <sub>2</sub> penetrated by lo  | ng acicular    | crystals of       | Rutile.   |
| 37 Sahlite            | Augite contg. Fe   |                |                   |           |
| 38 Sal ammoniac       | NH <sub>4</sub> Cl   | I.             | 1.52              | 1.5-2.0   |
| 39 Salmiak            | See Sal Ammoniac.  |                |                   |           |
| 40 Salt, Common       | See Rock Salt.   |                |                   |           |
| 41 Saltpetre          | See Nitre.   |                |                   |           |
| 42 Samarskite         | (Fe,Ce,Y,Er) <sub>4</sub> (Nb <sub>2</sub> O <sub>7</sub> ) <sub>3</sub> .<br>(Fe,Ce,Y,Er) <sub>6</sub> O<br>5 UO <sub>3</sub> | IV             | 5.6-5.8           | 5.5-6     |

| Lustre.      | Colour.          | Streak.  | Fracture.                    | Fusibility. | Solubility.                            |    |
|--------------|------------------|----------|------------------------------|-------------|--|----|
| Met.         | P.Br.            |          |                              |             |  | 1  |
| Vit.         | Y.W.             | Shining  |                              | Fus.        | s. $\text{HNO}_3 + \text{HCl}$         | 2  |
| Vit.—py.     | W., Gr., Y., G.  |          |                              |             |  | 3  |
|              | Rose R.,         | W.       | Uneven,                      | Inf.        | s. warm HCl                            | 4  |
|              | Y.Gr., Br.       |          | brittle                      |             |  |    |
| Vit.         | Flesh R., Br. R. | W.       | Uneven,                      | Fus. 2·5    | Ins. HCl                               | 5  |
|              | G., Y., Bl.      |          | conch.                       |             |  | 6  |
|              | W.               |          |                              |             |  | 7  |
|              |                  |          |                              |             |  | 8  |
| Vit.         | Cream Y.         |          |                              |             |  | 9  |
|              | Bl.              | ?        | $\infty \text{P } 124^\circ$ | E. fus.     |  |    |
| Vit.         | Y., Br. Y.       | ?        | $\infty \text{P } \infty$    | Fus.        | s. HCl with                            | 10 |
|              |                  |          |                              |             | sepn. of                               |    |
|              |                  |          |                              |             | powdery $\text{SiO}_2$                 |    |
| Py.          | G., Y., W.,      | W.       | Conch.                       | Fus.        | Decom. $\text{H}_2\text{SO}_4$         | 11 |
|              | R., V.           |          |                              |             |  |    |
|              | Y.G.             | Pale G.  |                              |             |  | 12 |
|              |                  |          |                              |             |  | 13 |
| water)       | W.               |          | Earthy, like                 |             |  | 14 |
|              |                  |          | chalk                        |             |  | 15 |
| Vit.         | C., W., P., Y.,  | C.       | Conch.                       | Fus.        | s. $\text{H}_2\text{O}$                | 16 |
|              | Purple           |          |                              |             |  | 17 |
| Vit.         | Y.               | Y.       |                              |             |  | 18 |
|              | Br.G.            |          |                              |             |  | 19 |
| Vit.         | R.               | ?        |                              | Fus.        | s. HCl                                 | 20 |
|              | P.               |          |                              | Fus.        | Gelatinous                             | 21 |
|              |                  |          |                              |             | $\text{SiO}_2$ with HCl                |    |
| Vit.         | Rose P.          | R.       | Conch.                       | Inf.        | s. HF                                  | 22 |
| Vit.         | Y.Br.—R.Br.      | Br.      | Conch.                       | 3           |  | 23 |
| Dull         | G.               |          | Earthy                       |             |  | 24 |
| Vit.         | B.G.             | ?        | Conch.                       | Inf.        | Gelatinous                             | 25 |
|              |                  |          |                              |             | $\text{SiO}_2$ with HCl                |    |
|              | R.               |          |                              |             |  | 26 |
|              | Orange R.        |          |                              |             |  | 27 |
|              | Violet           |          |                              |             |  | 28 |
|              | Rose R.          |          |                              |             |  | 29 |
| Vit.         | R.               |          | Conch.,                      | Inf.        | Ins.                                   | 30 |
|              |                  |          | uneven                       |             |  |    |
|              |                  |          |                              |             |  | 31 |
|              | Ruby R.          |          |                              |             |  | 32 |
| Vit. res.    | Bl.Br.           |          |                              |             |  | 33 |
| Sub-met. ad. | R.Br.—R.—        | Pale Br. | Conch.                       | Inf.        | s. $\text{H}_2\text{SO}_4 + \text{HF}$ | 34 |
|              | Bl.              |          |                              |             |  |    |
|              | Tin W.           | W.       |                              |             |  | 35 |
|              |                  |          |                              |             |  | 36 |
| Coarse, dull | G.               |          |                              |             |  | 37 |
| Vit.         | W., Y., Gr.      | W.       | Conch.                       | Sublimes    | E.s. $\text{H}_2\text{O}$              | 38 |
|              |                  |          |                              |             |  | 39 |
|              |                  |          |                              |             |  | 40 |
|              |                  |          |                              |             |  | 41 |
| Sub-met.     | Velvet Bl.       | Dark     | Conch.                       | D. fus.     | D.s. HCl                               | 42 |
|              |                  | R.Br.    |                              |             |  |    |

| Name.                              | Composition.  | Cryst. System.                       | Specific Gravity.   | Hardness. |
|------------------------------------|---|--------------------------------------|---------------------|-----------|
| 1 Sanidine                         | Glassy Orthoclase   | V.                                   | 2.39—2.62           | 6         |
| 2 Sapphire, True                   | $\text{Al}_2\text{O}_3$   | III.rh.                              | 3.90—4.16           | 9         |
| 3 — Brazilian                      | Tourmaline (q.v.)   |                                      |                     |           |
| 4 Sapphirine                       | 5 $\text{MgO} \cdot 6 \text{Al}_2\text{O}_3 \cdot 2 \text{SiO}_2$   | V.                                   | 3.5                 | 7.5       |
| 5 Sarcolite                        | 3 $(\text{Ca}, \text{Na}_2)\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 3 \text{SiO}_2$   | II.pyr.h.                            | 2.5—2.9             | 6         |
| 6 Sardonyx                         | Chalcedony. (Flat-banded variety)   | nded variety                         | y, composed of blue |           |
| 7 Sassoline                        | 3 $\text{H}_2\text{O} \cdot \text{B}_2\text{O}_3$   | VI.                                  | 1.48                | 1         |
| 8 Satin Spar                       | Compact fibrous variety of calcite, like satin or fibrous variety of gypsum.  | ty of calcite, like satin or gypsum. |                     |           |
| 9 Saussurite                       | Impure Labradorite  |                                      | 3.25—3.38           | 7         |
| 10 Scapolite                       | 4 $\text{CaO} \cdot 3 \text{Al}_2\text{O}_3 \cdot 6 \text{SiO}_2$ or 2 $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 9 \text{SiO}_2$ with Cl | II.                                  | 2.6—2.8             | 5—6       |
| 11 Scheelite                       | $\text{CaWO}_4$   | II.h.                                | 5.9—6.075           | 4.5—5     |
| 12 Schiller Spar                   | Alteration product of enstatite or bronzite   |                                      | 2.5—2.7             | 3.5—4     |
| 13 Schorl                          | Tourmaline (q.v.)   |                                      |                     |           |
| 14 Schorlomite                     | 3 $(\text{Ca}, \text{Fe})\text{O} \cdot 4 \text{Al}_2\text{O}_3 \cdot 15 \text{SiO}_2$ with Ti  |                                      | 3.80                | 7—7.5     |
| 15 Schwatzite                      | Mercuriferous Tetrahydrate.   | drite.                               |                     |           |
| 16 Scolecite                       | $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3 \text{SiO}_2 \cdot 2 \text{H}_2\text{O}$  | V. or VI.                            | 2.24—2.26           | 5—5.5     |
| 17 Scorodite                       | $\text{FeAsO}_4 \cdot 2 \text{H}_2\text{O}$   | IV.                                  | 3.1—3.3             | 3.5—4     |
| 18 Selenide, Copper (Berzelianite) | $\text{Cu}_2\text{Se}$  | ?                                    | 6.71                | 2.5—3     |
| 19 — Copper Lead (Zorgite)         | $(\text{Pb}, \text{Cu}_2)\text{Se}$   |                                      | 7—7.5               | 1         |
| 20 — Lead (Clausthalite)           | $\text{PbSe}$   | I.                                   | 8.2—9.0             | 2.5—3     |
| 21 — Mercury (Tiemannite)          | $\text{HgSe}$   | I.tetr.h.                            | 8.19                | 2.5       |
| 22 — Silver (Naumannite)           | $\text{Ag}_2\text{Se}$  | I.                                   | 8                   | 2.5       |
| 23 Selenite                        | See Gypsum.   |                                      |                     |           |
| 24 Sellaite                        | $\text{MgF}_2$  | II.                                  | 2.97—3              | 5         |
| 25 Selwynite                       | See Ochre, Yellow   |                                      |                     |           |
| 26 Semiopal                        | $\text{SiO}_2$  |                                      |                     |           |
| 27 Senarmontite                    | $\text{Sb}_2\text{O}_3$   | I.                                   | 5.2                 | 2—2.5     |
| 28 Sepiolite                       | 2 $\text{MgO} \cdot 3 \text{SiO}_2 \cdot 2 \text{H}_2\text{O}$  | Am.                                  | <1                  | 2—2.5     |
| 29 Sericite                        | Flaky Muscovite.  |                                      | 2.8                 |           |
| 30 Serpentine                      | 2 $\text{H}_2\text{O} \cdot 3 (\text{Mg}, \text{Fe})\text{O} \cdot 2 \text{SiO}_2$  | IV.                                  | 2.5—2.7             | 3—4       |
| 31 Seybertite                      | 6 $(\text{Fe}, \text{Ca})\text{O} \cdot 9 (\text{Fe}, \text{Al})_2\text{O}_3 \cdot 5 \text{SiO}_2 \cdot \frac{1}{2} \text{H}_2\text{O}$               | V.                                   | 3                   | 4.5       |
| 32 Siderazote                      | $\text{Fe}_3\text{N}_2$ (Incrustation on Mount Etna.)   | on Mount Etna.)                      |                     |           |
| 33 Siderite                        | $\text{FeCO}_3$   | III.rh.                              | 3.7—3.9             | 3—4.5     |
| 34 Silica                          | See Quartz.   |                                      |                     |           |
| 35 Silicate, Copper                | See Chrysocolla.  |                                      |                     |           |
| 36 — Manganese                     | See Rhodonite.  |                                      |                     |           |
| 37 — Nickel                        | See Garnierite, Genthi te.  |                                      |                     |           |
| 38 — Zinc                          | See Willemite, Hemimorphite.  |                                      |                     |           |
| 39 Siliceous Sinter                | $\text{SiO}_2$ deposited round geysers.   |                                      |                     |           |
| 40 Silicified Wood                 | Fibrous material of vegetation replaced by silica.  |                                      |                     |           |

| Lustre.       | Colour.                    | Streak. | Fracture.               | Fusibility.  | Solubility.   |    |
|---------------|----------------------------|---------|-------------------------|--------------|---|----|
| Vit.          | C.                         | C.      | Conch.                  | Fus.         |   | 1  |
| Vit.          | B.                         |         | Conch.                  | Inf.         | Ins.  | 2  |
|               | Berlin B., tr.             |         |                         |              |   | 3  |
| Vit.          | W.B.                       |         | Uneven                  | Inf.         | Ins.  | 4  |
| Vit.          | P., P.W.                   |         | Conch.                  | Fus.         | Gelatinous<br>SiO <sub>2</sub> with HCl                     | 5  |
| and white or  | red and white layers.)     |         |                         |              |   | 6  |
| Py.           | W., Gr., Y.<br>tl.-tr.     | W.      | Sectile and<br>flexible | 1            | s. H <sub>2</sub> O and<br>C <sub>2</sub> H <sub>5</sub> OH | 7  |
|               |                            |         |                         |              |   | 8  |
|               |                            |         |                         |              |   | 9  |
| Vit. py. res. | W., B., G.,<br>P. tr.-op.  | C.      | Sub-conch.,<br>brittle  | Fus.         | Part decomp.<br>HCl   | 10 |
| Vit.          | Y.W., Br.,<br>Or. Y.       | W. tr.  | Uneven,<br>brittle      | 5            | s. HCl with<br>sepn. of WO <sub>3</sub>                     | 11 |
| Met. py.      | G., G.Bl., Br.             |         |                         |              |   | 12 |
|               | Bl. op.                    |         |                         |              |   | 13 |
|               | Bl.                        | Gr.Bl.  |                         | E. fus.      | E. decomp. ac.<br>with sepn. of<br>gel. SiO <sub>2</sub>    | 14 |
|               |                            |         |                         |              |   | 15 |
| Vit. or py.   | W., Y., Gr., R.            |         |                         | Fus.         |   | 16 |
| Vit.          | G., B., Br.                | W.G.    | Uneven                  | 2—3          | s. HCl  | 17 |
| Met.          | Gr.                        | Gr.     | Earthy                  | Fus.         | s. HNO <sub>3</sub>   | 18 |
| Met.          | Gr.                        | Gr.     | Friable                 | 1            | s. HNO <sub>3</sub>   | 19 |
| Met.          | Gr.                        | Gr.     | ∞O∞                     | Inf.         | s. HNO <sub>3</sub>   | 20 |
| Met.          | Gr.                        | Gr.Bl.  | Conch.,<br>uneven       | E. fus. vol. | s. HNO <sub>3</sub> + HCl                                   | 21 |
| Met.          | Gr.Bl.                     | Bl.     | ∞O∞                     | Fus.         | s. fuming<br>HNO <sub>3</sub>                               | 22 |
| Py.           | W.                         |         |                         |              |   | 23 |
| Vit.          | C.                         |         | ∞P∞                     | E. fus.      | Decom. H <sub>2</sub> SO <sub>4</sub>                       | 24 |
|               |                            |         |                         |              |   | 25 |
|               | W., tl.                    |         |                         |              |   | 26 |
| Ad. greasy    | C., W., Gr.                |         | Uneven                  | Fus. vol.    | s. HCl  | 27 |
| Soapy         | W., Gr.W.,<br>Y., P.       | W.      | Earthy                  |              | Gelatinous<br>SiO <sub>2</sub> with HCl                     | 28 |
| Sy.           | G., Y.W.                   |         |                         |              |   | 29 |
| Res. soapy    | G.Gr., Br.                 | G.W.    | Conch.,<br>fibrous      | 5·5          |   | 30 |
| Py. sub-met.  | R.Br., Y.Br.,<br>Copper R. | Br.     | Foliated                |              |   | 31 |
| Steel-like    |                            |         |                         |              |   | 32 |
| Py.           | Gr.W.—Br.—<br>R.           | C.      | Conch.                  | Inf.         | s. hot HCl  | 33 |
|               |                            |         |                         |              |   | 34 |
|               |                            |         |                         |              |   | 35 |
|               |                            |         |                         |              |   | 36 |
|               |                            |         |                         |              |   | 37 |
|               |                            |         |                         |              |   | 38 |
|               |                            |         |                         |              |   | 39 |
|               |                            |         |                         |              |   | 40 |

| Name. |                  | Composition.  | Cryst. System. | Specific Gravity. | Hardness. |
|-------|------------------|---|----------------|-------------------|-----------|
| 1     | Silver Amalgam   | $\text{AgHg}_2$   | I.             | 10.5—14           | 3—3.5     |
| 2     | — Glance         | See Argentite.  |                |                   |           |
| 3     | — Lead Ore       | $\text{PbS}$ (argentiferous)  | I.             |                   |           |
| 4     | — Native         | $\text{Ag}$   | I.             | 10.1—11.1         | 2.5—3     |
| 5     | Sinter, Iron     | See Scorodite. (Amorphous variety.)   |                |                   |           |
| 6     | Sipylite         | $(\text{Y,Er})\text{NbO}_4$ with $\text{Ce}$  | II.            | 4.88—4.89         | 5.5—6     |
| 7     | Smaltine         | $\text{CoAs}_2$   | I.             | 6.4—7.2           | 5.5—6     |
| 8     | *Smithsonite     | $2 \text{ZnO} \cdot \text{SiO}_2 + \text{H}_2\text{O}$  | IV.            | 3.16—3.49         | 4.5—5     |
| 9     | Soapstone        | See Talc.   |                |                   |           |
| 10    | Sodalite         | $3 \text{NaAlSiO}_4 + \text{NaCl}$  | I.             | 2.13—2.26         | 5.5—6     |
| 11    | Soda Nitre       | $\text{NaNO}_3$   | III.rh.        | 2.09—2.29         | 1.5—2     |
| 12    | Spartalite       | $\text{ZnO}$  | III.           | 5.4—5.7           | 4—4.5     |
| 13    | Spathic Iron Ore | See Chalybite.  |                |                   |           |
| 14    | Spear Pyrites    | See Marcasite.  |                |                   |           |
| 15    | Specular Iron    | See Red Hematite.   |                |                   |           |
| 16    | Spessartite      | See Garnet, Manganese-Alumina.  |                |                   |           |
| 17    | Sphalerite       | See Blende, Zinc.   |                |                   |           |
| 18    | Sphene           | $\text{CaO} \cdot \text{TiO}_2 \cdot \text{SiO}_2$  | V.             | 3.4—3.56          | 5—5.5     |
| 19    | Spinel           | $\text{MgO} \cdot \text{Al}_2\text{O}_3$  | I.             | 3.5—3.6           | 8         |
| 20    | — Ruby           | See Spinel.   |                |                   |           |
| 21    | Spodumene        | $\text{Li}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4 \text{SiO}_2$  | V.             | 3.13—3.19         | 6.5—7     |
| 22    | Stannine         | $2 \text{Cu}_2\text{S} \cdot (\text{Fe,Zn})\text{S} \cdot \text{SnS}_2$                                       | I.tetr.        | 4.3—4.5           | 4         |
| 23    | Staurolite       | $\text{H}_2\text{O} \cdot 2 \text{FeO} \cdot 5 \text{Al}_2\text{O}_3 \cdot 4 \text{SiO}_2$                    | IV.            | 3.4—3.8           | 7—7.5     |
| 24    | Staurolite       | See Staurolite.   |                |                   |           |
| 25    | Steatite         | See Talc.   |                |                   |           |
| 26    | Stephanite       | $5 \text{Ag}_2\text{S} \cdot \text{Sb}_2\text{S}_3$   | IV.            | 6.26              | 2—2.5     |
| 27    | Sternbergite     | $(\text{Ag}_2,\text{Fe})\text{S}$   |                | 4.215             | 1.5—2     |
| 28    | Stibnite         | See Antimony Blende.  |                |                   |           |
| 29    | Stilbite         | $(\text{Na}_2,\text{Ca})\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6 \text{SiO}_2 \cdot 6 \text{H}_2\text{O}$ | V.             | 2—2.2             | 3.5—4     |
| 30    | Stilpnomelane    | $2 \text{FeO} \cdot \text{SiO}_2$ with $\text{Al}$ , $\text{Ca}$ , $\text{Mg}$ , etc.                         | ?              | 3—3.4             | 3—4       |
| 31    | Stinkstone       | See Anthraconite.   |                |                   |           |
| 32    | Stolzite         | $\text{PbWO}_4$   | II.            | 7.9—8.1           | 2.5—3     |
| 33    | Strengite        | $\text{FePO}_4 \cdot 2 \text{H}_2\text{O}$  | IV.            | 2.8—2.91          | 3—4       |

\*This is taken as the English name, and is the "Calamine" of Dana.

| Lustre.      | Colour.                          | Streak.        | Fracture.                       | Fusibility.                          | Solubility.   |                                  |
|--------------|----------------------------------|----------------|---------------------------------|--------------------------------------|---|----------------------------------|
| Met.         | Silver W. op.                    | W. op.         | Brittle<br>conch.,<br>uneven    | Fus., Hg<br>vol.                     | s. $\text{HNO}_3$   | 1                                |
| Met.         | Gr.W.                            | Gr.            |                                 |                                      |   | 2                                |
| Met.         | Silver W.                        | W.,<br>shining | Section,<br>malleable           | E. fus.<br>Fus.                      | s. $\text{HNO}_3$<br>s. $\text{HNO}_3$                              | 3<br>4                           |
| Met. res.    | Br.Bl.                           | Br.Gr.         | Conch.,<br>uneven               | Inf.                                 |   | 5<br>6                           |
| Met.         | Tin W.—Gr.                       | Gr.Bl.         | Granular,<br>brittle            | Fus. $\text{As}_2\text{O}_3$<br>vol. | s. $\text{HNO}_3$ with<br>sepn. of<br>$\text{As}_2\text{O}_3$       | 7                                |
| Vit. subpy.  | W., Y., Br.,<br>G., B.           | W.             | Brittle                         | Very d.<br>fus.                      | s. conc. KOH<br>soln.   | 8                                |
| Vit.         | Gr., B., Y.,<br>&c.              | C.             | Conch.,<br>uneven               | 3·5                                  | Gelatinous<br>$\text{SiO}_2$ with HCl<br>or $\text{HNO}_3$          | 9<br>10                          |
| Vit.         | W., Gr., Y.,<br>R.Br.            | C.             | Conch.                          | Fus.                                 | s. $\text{H}_2\text{O}$   | 11                               |
| Sub-ad.      | Deep R                           | Orange Y       | Brittle                         | Inf.                                 | s. ac.  | 12<br>13<br>14<br>15<br>16<br>17 |
| Ad. or res.  | Br., Gr., Br.Gr.,<br>Y., G., Bl. | W.             | Imperfect<br>conch.,<br>brittle | 5                                    | Decom. $\text{H}_2\text{SO}_4$                                      | 18                               |
| Vit.         | R., Br., Bl.,<br>G., B.          |                | Conch.                          | Inf.                                 | D.s. conc.<br>$\text{H}_2\text{SO}_4$                               | 19                               |
| Py.—vit.     | Gr.G. tl.—stl.                   | C.             | Uneven                          | 3·5                                  | Ins.  | 20<br>21                         |
| Met.         | Steel Gr., Bl.,<br>Bronze        | Bl.            | Uneven,<br>brittle              | D. fus.                              |   | 22                               |
| Subvit.—res. | R.Br., Br.Bl.,<br>Y.Br.          | C. or Gr.      | Conch.                          | E. fus. (Mn)<br>or Inf. (Fe)         | Ins.  | 23<br>24<br>25                   |
| Met.         | Iron Bl.                         | Bl.            | Uneven                          | Fus.                                 | s. $\text{HNO}_3$ with<br>sepn. of S<br>and $\text{Sb}_2\text{O}_3$ | 26                               |
| Met.         | Pinchbeck Br.                    | Bl.            | Like<br>graphite                | E. fus.                              | s. $\text{HNO}_3$   | 27<br>28<br>29                   |
| Py. vit.     | W., Y., Br., R.                  | C.             | Conch.                          | Fus.                                 |   |                                  |
| Vit. greasy  | B., G.Bl.                        | G., G.Gr.      | Regular                         | Fus.                                 | D. decomp.<br>HCl   | 30<br>31                         |
| Res          | G., Gr., Br., R.                 |                | Conch.                          | E. fus.                              | s. $\text{HNO}_3$ with<br>sepn. of $\text{WO}_3$<br>S.KOH           | 32                               |
| Vit. py.     | C., P.                           |                | Imperfect<br>conch.             | E. fus.                              | E.s. HCl, Ins.<br>$\text{HNO}_3$                                    | 33                               |



| Name. |                     | Composition.  | Cryst. System. | Specific Gravity. | Hardness |
|-------|---------------------|---|----------------|-------------------|----------|
| 1     | Stromeyerite        | $\text{Ag}_2\text{S} + \text{Cu}_2\text{S}$                               |                | 6.26              | 2.5—3    |
| 2     | Strontianite        | $\text{SrCO}_3$   | IV.            | 3.6—3.8           | 3.5      |
| 3     | Struvite            | $(\text{NH}_4)\text{MgPO}_4 \cdot 6\text{H}_2\text{O}$                    | IV. (h.)       | 1.66—1.75         | 1.5      |
| 4     | Succinite           | See Garnet, Lime-Alumina.   |                |                   |          |
| 5     | Sulphate, Aluminium | See Aluminite, Alunogene.   |                |                   |          |
| 6     | — Ammonium          | See Mascagnine.   |                |                   |          |
| 7     | — Barium            | See Barytes.  |                |                   |          |
| 8     | — Calcium           | See Anhydrite, Gypsum.  |                |                   |          |
| 9     | — Cobalt            | See Bieberite.  |                |                   |          |
| 10    | — Copper            | See Chalcantite.  |                |                   |          |
| 11    | — Iron              | See Copperas.   |                |                   |          |
| 12    | — Lead              | See Anglesite.  |                |                   |          |
| 13    | — Magnesium         | See Epsom Salt.   |                |                   |          |
| 14    | — Nickel            | See Morenosite.   |                |                   |          |
| 15    | — Sodium            | See Glaubersalt, Thenardite.  |                |                   |          |
| 16    | — Strontium         | See Celestine.  |                |                   |          |
| 17    | — Uranium           | See Uranvitriol.  |                |                   |          |
| 18    | — Zinc              | See Goslarite.  |                |                   |          |
| 19    | Sulphide, Antimony  | See Antimony Blende.  |                |                   |          |
| 20    | — Arsenic           | See Realgar, Orpiment.  |                |                   |          |
| 21    | — Bismuth           | See Bismuthine.   |                |                   |          |
| 22    | — Cadmium           | See Greenockite.  |                |                   |          |
| 23    | — Cobalt            | See Linnaeite.  |                |                   |          |
| 24    | — Copper            | See Bornite, Copper Pyrites.  |                |                   |          |
| 25    | — Iron              | See Iron Pyrites.   |                |                   |          |
| 26    | — Lead              | See Galena.   |                |                   |          |
| 27    | — Manganese         | See Alabandin   |                |                   |          |
| 28    | — Mercury           | See Cinnabar.   |                |                   |          |
| 29    | — Molybdenum        | See Molybdenite.  |                |                   |          |
| 30    | — Nickel            | See Millerite.  |                |                   |          |
| 31    | — Silver            | See Argentite.  |                |                   |          |
| 32    | — Tin               | See Stannine.   |                |                   |          |
| 33    | — Zinc              | See Sphalerite.   |                |                   |          |
| 34    | Sulphur, Native     | S   | IV.            | 2.07              | 1.5—2.5  |
| 35    | Sunstone            | Orthoclase (q.v.) [translucent with minute spangles]                      |                |                   |          |
| 36    | Sussexite           | $(\text{Mg}, \text{Mn})\text{B}_4\text{O}_7 \cdot \text{aq}$              | ?              | 3.42              |          |
| 37    | Sylvanite           | See Graphic Tellurium.  |                |                   |          |
| 38    | Sylvine             | KCl   | I.             | 1.9—2             | 2        |
| 39    | Tabular Spar        | See Wollastonite.   |                |                   |          |
| 40    | Tachyhydrite        | $\text{CaCl}_2 \cdot 2\text{MgCl}_2 \cdot 12\text{H}_2\text{O}$           | III.rh.        | 1.9—2             | 2        |
| 41    | Talc                | $\text{H}_2\text{O} \cdot 3\text{MgO} \cdot 4\text{SiO}_2$                | IV.            | 2.5—2.8           | 1 (1.5)  |
| 42    | Tantalite           | $(\text{Fe}, \text{Mn})\text{O} \cdot (\text{Nb}, \text{Ta})_2\text{O}_5$ | IV.            | 7—8               | 6—6.5    |
| 43    | Tapiolite           | $\text{FeO} \cdot (\text{Nb}, \text{Ta})_2\text{O}_5$                     | II.            | 7.3—7.5           | 6        |
| 44    | Tarapacaité         | $\text{K}_2\text{CrO}_4$  |                |                   |          |
| 45    | Telluric Bismuth    | $\text{Bi}_2(\text{S}, \text{Te})_3$                                      | III.           | 7.2—7.9           | 1.5—2    |
| 46    | — Ochre             | $\text{TeO}_2$  | Am.            |                   |          |
| 47    | Telluride, Gold     | $\text{AuTe}_2$   |                | 9.043             | 1.5—2    |
| 48    | — Lead              | See Nagyagite.  |                |                   |          |
| 49    | — Silver            | See Tellurium, Graphitic.   |                |                   |          |
| 50    | Tellurium, Foliated | See Nagyagite.  |                |                   |          |
| 51    | — Graphitic         | $(\text{Ag}, \text{Au})\text{Te}_2$                                       | V.             | 7.9—8.33          | 1.5—2.0  |



| Lustre.              | Colour.                              | Streak.   | Fracture.                    | Fusibility. | Solubility.                             |    |
|----------------------|--------------------------------------|-----------|------------------------------|-------------|---|----|
| Met.                 | Steel Gr.                            | Gr.       | Conch.                       | Fus.        | s. HNO <sub>3</sub>                     | 1  |
| Vit.                 | C., W., Y., P.                       |           | Conch.,<br>uneven            | 5           | s. HCl                                  | 2  |
| Vit. res             | C., Y.<br>Amber Y.                   |           | oP, ∞ P ∞                    |             |   | 3  |
|                      |                                      |           |                              |             |   | 4  |
|                      |                                      |           |                              |             |   | 5  |
|                      |                                      |           |                              |             |   | 6  |
|                      |                                      |           |                              |             |   | 7  |
|                      |                                      |           |                              |             |   | 8  |
|                      |                                      |           |                              |             |   | 9  |
|                      |                                      |           |                              |             |   | 10 |
|                      |                                      |           |                              |             |   | 11 |
|                      |                                      |           |                              |             |   | 12 |
|                      |                                      |           |                              |             |   | 13 |
|                      |                                      |           |                              |             |   | 14 |
|                      |                                      |           |                              |             |   | 15 |
|                      |                                      |           |                              |             |   | 16 |
|                      |                                      |           |                              |             |   | 17 |
|                      |                                      |           |                              |             |   | 18 |
|                      |                                      |           |                              |             |   | 19 |
|                      |                                      |           |                              |             |   | 20 |
|                      |                                      |           |                              |             |   | 21 |
|                      |                                      |           |                              |             |   | 22 |
|                      |                                      |           |                              |             |   | 23 |
|                      |                                      |           |                              |             |   | 24 |
|                      |                                      |           |                              |             |   | 25 |
|                      |                                      |           |                              |             |   | 26 |
|                      |                                      |           |                              |             |   | 27 |
|                      |                                      |           |                              |             |   | 28 |
|                      |                                      |           |                              |             |   | 29 |
|                      |                                      |           |                              |             |   | 30 |
|                      |                                      |           |                              |             |   | 31 |
|                      |                                      |           |                              |             |   | 32 |
|                      |                                      |           |                              |             |   | 33 |
| Res.                 | Sulphur Y. or<br>tinted G.<br>or Or. | Y.        | Sectile ;<br>very<br>brittle | E. fus.     | Ins.                                    | 34 |
| of mica dis          | seminated thr                        | oughout]  |                              |             |   | 35 |
| Py.                  | W., P., Y.                           |           | Fibrous                      |             |   | 36 |
| Vit.                 | W., C., P., Y.                       |           | ∞ O ∞                        | 2           | E.s. H <sub>2</sub> O                   | 37 |
| Vit.                 | C., Y., W.                           | C.        |                              | 1           | s. H <sub>2</sub> O                     | 38 |
| Py.                  | W., G., Gr.,<br>Gr.G.                | W., Gr.G. | Foliated                     | 6           | Ins.                                    | 39 |
| Ad., met.,<br>greasy | Gr.Bl.                               | Bl.Br.    | Conch.,<br>uneven            | Inf.        | Ins.                                    | 40 |
| Met.                 | Bl.                                  | Bl.       |                              | D. fus.     | Ins.                                    | 41 |
| Vit. res.            | Y., Or.                              | Y.        |                              |             |   | 42 |
| Splendent            | Pale steel Gr.                       | Gr.Bl.    | oR                           | 1           | s. HNO <sub>3</sub> with<br>sepn. of S. | 43 |
| met.                 | W., Y.                               | W.Y.      | Earthy                       |             |   | 44 |
| Earthy               | Y. (Bronze)                          | Y.W.      |                              |             |   | 45 |
| Met.                 |                                      |           |                              |             |   | 46 |
|                      |                                      |           |                              |             |   | 47 |
|                      |                                      |           |                              |             |   | 48 |
|                      |                                      |           |                              |             |   | 49 |
| Met.                 | Steel Gr.—<br>silver W.              | Gr.W.     | ∞ P ∞                        | Fus.        | s. HNO <sub>3</sub> with<br>sepn. of Au | 50 |
|                      |                                      |           |                              |             |   | 51 |

| Name. |                   | Composition.   | Cryst. System.              | Specific Gravity.           | Hardness. |
|-------|-------------------|--|-----------------------------|-----------------------------|-----------|
| 1     | Tellurium, Native | Te   | III.rh.                     | 6.1—6.3                     | 2—2.5     |
| 2     | Tennantite        | 4 Cu <sub>2</sub> S.As <sub>2</sub> S <sub>3</sub> with Fe   | I.                          | 4.5—4.9                     | 4         |
| 3     | Tenorite          | CuO  | Am. or VI.                  | 6.25                        | 3         |
| 4     | Teratolite        | Fe <sub>2</sub> O <sub>3</sub> , Mn <sub>2</sub> O <sub>3</sub> +<br>decomp. Felspar   | Am.                         | 2.5                         | 2.5—3     |
| 5     | Tetradymite       | See Telluric Bismuth.  |                             |                             |           |
| 6     | Tetrahedrite      | 4 Cu <sub>2</sub> S.Sb <sub>2</sub> S <sub>3</sub>   | I.                          | 4.5—5.1                     | 3—4.5     |
| 7     | Thalenite         | 2 Y <sub>2</sub> O <sub>3</sub> .4 SiO <sub>2</sub> .H <sub>2</sub> O  | V.                          | 4.23 (R.)<br>4.11—4.16 (Y.) | 6.5       |
| 8     | Thenardite        | Na <sub>2</sub> SO <sub>4</sub>  | IV.                         | 2.7                         | 2.5       |
| 9     | Thermonatrite     | Na <sub>2</sub> CO <sub>3</sub> .H <sub>2</sub> O  | IV.                         | 1.6                         | 1.5—2     |
| 10    | Thomsonolite      | NaF.CaF <sub>2</sub> .AlF <sub>3</sub> .H <sub>2</sub> O   | V.                          |                             |           |
| 11    | Thomsonite        | 2 (Ca,Na) <sub>2</sub> O.2 Al <sub>2</sub> O <sub>3</sub> .<br>4 SiO <sub>2</sub> .5 H <sub>2</sub> O  | IV.                         | 2.3—2.4                     | 5—5.5     |
| 12    | Thorite           | ThO <sub>2</sub> .SiO <sub>2</sub> contg.<br>(Ca,Fe,Mn,U)  | II.                         | 4.4—4.7                     | 4.5       |
| 13    | Thulite           | Zoisite (q.v.)   |                             |                             |           |
| 14    | Thuringite        | 4 (Al,Fe) <sub>2</sub> O <sub>3</sub> .7 FeO.<br>6 SiO <sub>2</sub> .9 H <sub>2</sub> O  | Am.                         | 3.15—3.20                   | 2—2.5     |
| 15    | Tiemannite        | HgSe   |                             |                             |           |
| 16    | Tile Ore          | See Cuprite.   |                             |                             |           |
| 17    | Tincal            | See Borax.   |                             |                             |           |
| 18    | Tin Stone         | See Cassiterite.   |                             |                             |           |
| 19    | — Pyrites         | See Stannine.  |                             |                             |           |
| 20    | Titanic Iron      | See Ilmenite.  |                             |                             |           |
| 21    | Titanite          | CaO.TiO <sub>2</sub> .SiO  | V.                          | 3.4—3.56                    | 5—5.5     |
| 22    | Topaz             | Al <sub>2</sub> O <sub>3</sub> .SiO <sub>2</sub>   | IV.                         | 3.4—3.65                    | 8         |
| 23    | — False           | SiO <sub>2</sub> (quartz)  | III.rh.                     | 2.5—2.8                     | 7         |
| 24    | — Oriental        | Corundum (q.v.)  |                             |                             |           |
| 25    | Topazolite        | See Garnet, Iron-lime.   |                             |                             |           |
| 26    | Torbanite         | Variety of Cannel, remarkable for high ash   |                             |                             | and       |
| 27    | Torbernite        | (CuO+2 U <sub>2</sub> O <sub>3</sub> ).P <sub>2</sub> O <sub>5</sub> +<br>8 H <sub>2</sub> O (See Chalcocite.)   |                             |                             |           |
| 28    | Touchstone        | See Lydian Stone.  |                             |                             |           |
| 29    | Tourmaline        | 4 (Li, Na) <sub>2</sub> O . 4 FeO .<br>6 B <sub>2</sub> O <sub>3</sub> . 15 Al <sub>2</sub> O <sub>3</sub> .<br>24 SiO <sub>2</sub> 7 H <sub>2</sub> O . (Li<br>variety). Also Fe<br>and Mg varieties. | III.rh.                     | 2.9—3.3                     | 7—7.5     |
| 30    | Traversellite     | Augite with little<br>Al <sub>2</sub> O <sub>3</sub>   | Long<br>fibrous<br>crystals |                             |           |

| Lustre.     | Colour.                        | Streak. | Fracture.                                   | Fusibility. | Solubility.  |    |
|-------------|--------------------------------|---------|---|-------------|--|----|
| Met.        | W.                             | Tin W.  | Imperfect                                   | E. fus.     | Oxidised by $\text{HNO}_3$ to $\text{H}_2\text{TeO}_3$   | 1  |
| Met.        | Lead Gr.—<br>Iron Bl.          | Gr.Bl.  | Uneven                                      | Fus.        | s. $\text{HNO}_3$ with<br>sepn. of S.<br>and $\text{As}_2\text{O}_3$                             | 2  |
| Dull        | Bl.                            | Bl.Br.  | Earthy                                      | Inf.        | s. ac.   | 3  |
| Dull        | B.                             | ?       | Uneven,<br>fine earth                       |             |  | 4  |
|             |                                |         |   |             |  | 5  |
| Met.        | Steel Gr.—<br>Iron Bl.         | Gr.Bl.  | Uneven,<br>sub-conch.,<br>rather<br>brittle | Fus.        | s. $\text{HNO}_3$ with<br>sepn. of S.,<br>$\text{As}_2\text{O}_3$ and<br>$\text{Sb}_2\text{O}_3$ | 6  |
| Greasy      | R.Y                            |         | Uneven,<br>splintery(R.)<br>conch. (Y.)     |             |  | 7  |
| Vit.        | C.W.P.                         | W.      | Uneven                                      | Fus.        | E.s. $\text{H}_2\text{O}$  | 8  |
| Vit.        | C.                             |         | $\infty \text{P} \infty$                    | E. fus.     | s. $\text{H}_2\text{O}$  | 9  |
| Py.         | C.                             |         | $\infty \text{P}$                           | E. fus.     |  | 10 |
| Vit.        | C., W., Gr., Y.,<br>P., G.     |         | $\infty \text{P} \infty$                    | 2           | Gelatinous<br>$\text{SiO}_2$ with<br>$\text{HCl}$  | 11 |
| Vit.        | Y.Br.                          | Y.      | Conch.,<br>splintery                        | Inf.        | Gelatinous<br>$\text{SiO}_2$ with<br>$\text{HCl}$  | 12 |
|             | R.                             |         |   |             |  | 13 |
| Py.         | G., Y.                         | G.Gr.   | Scaly                                       | E. fus.     | Gelatinous<br>$\text{SiO}_2$ with<br>$\text{HCl}$  | 14 |
| Met.        | Steel Gr.—Bl.                  | Gr.Bl.  |   | E. fus.     |  | 15 |
|             |                                |         |   |             |  | 16 |
|             |                                |         |   |             |  | 17 |
|             |                                |         |   |             |  | 18 |
|             |                                |         |   |             |  | 19 |
|             |                                |         |   |             |  | 20 |
| Ad.—res.    | Gr.Br., Br.—<br>Bl.<br>(Y.—G.) | C.      | Conch.                                      | Fus.        | Part. decomp.<br>$\text{HCl}$  | 21 |
| Vit.        | Pale Y., W.,<br>G., B., R.     | W.      | Conch.                                      | Inf.        | Ins.   | 22 |
| Vit.        | Lemon Y.<br>Y.                 |         | Conch.                                      | Inf.        | s. HF  | 23 |
|             | Wine Y.                        |         |   |             |  | 24 |
| large % gas | seous hydroca                  | rbons.  |   |             |  | 25 |
|             |                                |         |   |             |  | 26 |
|             |                                |         |   |             |  | 27 |
|             |                                |         |   |             |  | 28 |
| Vit.        | Bl., B.Bl., B.,<br>Gr., R.     | C.      | Sub-conch.<br>or uneven,<br>brittle         | 5·5—6       |  | 29 |
|             |                                |         | Asbestiform                                 |             |  | 30 |

| Name.                  | Composition.   | Cryst. System. | Specific Gravity. | Hardness. |
|------------------------|--|----------------|-------------------|-----------|
| 1 Tremolite            | $3 \text{ MgO} \cdot \text{SiO}_2 + \text{CaO} \cdot \text{SiO}_2$                     |                | 2.9—3.1           | 5—6.5     |
| 2 Tridymite            | $\text{SiO}_2$ (quartz)  |                | 2.28—2.33         | (Occurs   |
| 3 Tripestone           | Anhydrite (q.v.) (Concretionary)   |                |                   |           |
| 4 Triphylite           | $\text{Li}(\text{Fe}, \text{Mn})\text{PO}_4$   | IV.            | 3.54—3.6          | 5         |
| 5                      |  |                |                   |           |
| 6 Triplite             | $(\text{Fe}, \text{Mn})_2\text{FPO}_4$   | V.             | 3.5—3.8           | 5.5       |
| 7 Tripolite            | $\text{SiO}_2$   | (Secretions    | of microscop      | pic       |
| 8 Trippkeite           | $\text{CuAs}_2\text{O}_4$  | II.            |                   |           |
| 9 Trögerite            | $(\text{UO}_2)_2\text{As}_2\text{O}_7 \cdot 8 \text{ H}_2\text{O}$                     | V.             | 3.23              |           |
| Trona                  | $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2 \text{ H}_2\text{O}$              | V.             | 2.11              | 2.5—3     |
| 10 Troostite           | $2 (\text{Zn}, \text{Mn})\text{O} \cdot \text{SiO}_2$                                  | III.rh.t.      | 3.89—4.29         | 5.5—6     |
| 11 Tschermigite        | See Alum, Ammonium.  |                |                   |           |
| 12 Tufa                | $\text{CaCO}_3$ —water deposited.  |                |                   |           |
| 13 Tungstate, Iron     | See Wolfram.   |                |                   |           |
| 14 — Lead              | See Stolzite.  |                |                   |           |
| 15 — Lime              | See Scheelite.   |                |                   |           |
| 16 Tungstic Ochre      | $\text{WO}_3$  | Am.            | 6.3—7.2           | Soft      |
| 17 Tungstite           | See Tungstic Ochre.  |                |                   |           |
| 18 Turquoise           | $\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 + 5 \text{ H}_2\text{O}$             | Am             | 2.6—2.8           | 6         |
| 19 Tyrolite            | See Copper froth.  |                |                   |           |
| 20 Tysonite            | $(\text{Ce}, \text{La}, \text{Di})\text{F}_3$  | III.           |                   | Soft      |
| 21 Ulexite             | $\text{NaCaB}_4\text{O}_7 \cdot 8 \text{ H}_2\text{O}$                                 | Am.            | 1.65              | 1         |
| 22 Ullmannite          | $\text{NiSbS}$   | I. pent.       | 6.1—6.5           | 5—5.5     |
| 23 Ultramarine         | See Lapis Lazuli.  |                |                   |           |
| 24 Uraconite           | See Uranic Ochre.  |                |                   |           |
| 25 Uralite             | Amphibole  |                | 3.15              | 5         |
| 26 Uranic Ochre        | $\text{U}_2\text{O}_3$ mainly,<br>contg. Ra  | Am.            |                   | Soft      |
| 27 Uraninite           | See Pitchblende.   |                |                   |           |
| 28 Uranite, Copper     | See Torbernite.  |                |                   |           |
| 29 — Lime              | See Autunite.  |                |                   |           |
| 30 Uranospherite       | $\text{U}_2\text{O}_7(\text{BiO})_2 \cdot 3 \text{ H}_2\text{O}$<br>contg. Ra          |                | 6.36              | 2—3       |
| 31 Uranvitriol         | $\text{USO}_4$ contg. Cu   | V.             | 3.19              | 2—2.5     |
| 32 Uwarowite           | $6 \text{ CaO} \cdot 3 \text{ SiO}_2 + 2 \text{ Cr}_2\text{O}_3 \cdot 3 \text{ SiO}_2$ | I.             | 3.42              | 6.5—7.5   |
| 33 Valentinite         | $\text{Sb}_2\text{O}_3$  | IV.            | 5.4—5.62          | 2.5—3     |
| 34 Vanadinite          | $9 \text{ PbO} \cdot 3 \text{ V}_2\text{O}_5 \cdot \text{PbCl}_2$                      | III. pyr.      | 6.6—7.1           | 3         |
| 35 Variscite           | $\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5$ . aq                                | Am.            |                   |           |
| 36 Vanquelinite        | $2 \text{ PtO} \cdot \text{CuO} \cdot 2 \text{ CrO}_3$                                 | V.             | 5.5—5.8           | 2.5—3     |
| 37 Vermiculite         | $3 \text{ MgO} \cdot (\text{Fe}, \text{Al})_2\text{O}_3 \cdot 3 \text{ SiO}_2$         | ?              |                   |           |
| 38 Vermilion           | See Cinnabar.  |                |                   |           |
| 39 Vesuvianite         | See Idocrase.  |                |                   |           |
| 40 Vitreous Copper Ore | See Redruthite.  |                |                   |           |
| 41 — Silver Ore        | See Argentite.   |                |                   |           |
| 42 Vitriol, Blue       | See Chalcantite.   |                |                   |           |
| 43 — Green             | See Copperas.  |                |                   |           |
| 44 — White             | See Goslarite.   |                |                   |           |
| 45 Vivianite           | $3 \text{ FeO} \cdot \text{P}_2\text{O}_5 \cdot 8 \text{ H}_2\text{O}$                 | V.             | 2.58—2.68         | 1.5—2     |

| Lustre.                    | Colour.             | Streak.       | Fracture.                      | Fusibility.             | Solubility.                 |    |
|----------------------------|---------------------|---------------|--------------------------------|-------------------------|-----------------------------|----|
| Vit.                       | W.—dark Gr.         |               | Conch. or Fibrous              | 4                       | Ins.                        | 1  |
| in triple hexagonal plates |                     | in trachyte.) |                                |                         |                             | 2  |
| Subres.                    | Gr.G.—B.Gr., Br.Bl. | Gr.W.         | oP                             | 1.5                     | s. HCl                      | 3  |
| Greasy diatoms, he         | Br. "Diatomite")    | Gr.G.         |                                | E. fus.                 | s. HCl                      | 4  |
| Met.                       | B.G.                | ?             | $\infty P \infty$ , $\infty P$ | E. fus.                 | E.s. HCl.                   | 5  |
|                            | Y.                  | ?             | $\infty P \infty$              |                         |                             | 6  |
| Vit.                       | C., Gr., Y.W.       | ?             |                                | Gives $H_2O$ and $CO_2$ | s. ac. and $H_2O$           | 7  |
|                            |                     |               |                                |                         |                             | 8  |
| Vit. greasy                | G., Y., R.Br. Gr.   | Y.            |                                | 6                       | Gelatinous $SiO_2$ with HCl | 9  |
|                            |                     |               |                                |                         |                             | 10 |
|                            |                     |               |                                |                         |                             | 11 |
|                            |                     |               |                                |                         |                             | 12 |
|                            |                     |               |                                |                         |                             | 13 |
|                            |                     |               |                                |                         |                             | 14 |
| Dull sy.                   | Bright Y.—Y.G.      | ?             | Pulverulent                    | Inf.                    | s. alk.                     | 15 |
|                            |                     |               |                                |                         |                             | 16 |
| Wax.                       | Turquoise B.—B.G.   | W.            | Conch.                         | Inf.                    | s. HCl                      | 17 |
|                            |                     |               |                                |                         |                             | 18 |
| Wax.                       | Y.Br.               | W.Y.          | Conch.                         | Fus.                    |                             | 19 |
| Dull                       | W.                  | W.            | Powdery                        | Fus.                    | Part s. $H_2O$              | 20 |
| Met.                       | Gr.Bl.              | Gr.Bl.        | Uneven                         | 1                       | s. aqua-regia               | 21 |
|                            |                     |               |                                |                         |                             | 22 |
|                            |                     |               |                                |                         |                             | 23 |
| Py.                        | Bl.G.               | Gr.G.         | Fibrous                        | 4                       | Decomp. ac.                 | 24 |
|                            | Lemon Y., Or.       | Y.            | Pulverulent                    |                         |                             | 25 |
|                            |                     |               |                                |                         |                             | 26 |
|                            |                     |               |                                |                         |                             | 27 |
|                            |                     |               |                                |                         |                             | 28 |
| Dull                       | R., Orange          | ?             | Scaly                          | Inf.                    | Ins.                        | 29 |
|                            |                     |               |                                |                         |                             | 30 |
| Vit.                       | G.                  | G.            | $\infty P$                     |                         | D.s. $H_2O$                 | 31 |
| Vit.                       | G.                  |               | Conch.                         | Inf.                    | Ins.                        | 32 |
| Ad. py.                    | W., Y., Gr.         |               | $\infty P \sim$                | 1                       | E.s. HCl                    | 33 |
| Greasy                     | Y., Br., R.         |               | Uneven                         | E. fus.                 | E.s. $HNO_3$                | 34 |
| Dull                       | Light G.—emerald G. | G.W.          |                                |                         |                             | 35 |
| Py.                        | Dark G.—Py.Bl.      | Y.Gr.         |                                | E. fus.                 | s. $HNO_3$ w. th Y. ppt.    | 36 |
| Py.                        | Gr., Br., Y., Br.   |               | Mica-like                      | D. fus.                 | Ins.                        | 37 |
|                            |                     |               |                                |                         |                             | 38 |
|                            |                     |               |                                |                         |                             | 39 |
|                            |                     |               |                                |                         |                             | 40 |
|                            |                     |               |                                |                         |                             | 41 |
|                            |                     |               |                                |                         |                             | 42 |
|                            |                     |               |                                |                         |                             | 43 |
| Py.—vit.                   | B.—G. W.            | B.            | Conch.                         | E. fus.                 | s. HCl                      | 44 |
|                            |                     |               |                                |                         |                             | 45 |

| Name. |                | Composition.   | Cryst. System. | Specific Gravity. | Hardness. |
|-------|----------------|--|----------------|-------------------|-----------|
| 1     | Volborthite    | 4 (Cu,Ca)O.V <sub>2</sub> O <sub>5</sub> .H <sub>2</sub> O   | IV. ?          | 3.49—3.55         | 3.5       |
| 2     | Voltaite       | 2 (Fe,Al) <sub>2</sub> O <sub>3</sub> .5 (Mg,Fe,<br>Na <sub>2</sub> ,K <sub>2</sub> )(OH) <sub>2</sub> .(SO <sub>4</sub> ) <sub>2</sub> .<br>14 H <sub>2</sub> O | II. ?          | 2.6—2.79          | 3.5       |
| 3     | Voltzite       | 4 ZnS+ZnO  | Am.            |                   |           |
| 4     | Vulpinite      | Anhydrite (q.v.)   | Am.            |                   |           |
| 5     | Wad            | MnO with BaO & H <sub>2</sub> O  | Am.            | 3—4.26            | 0.5—6     |
| 6     | Wagnerite      | Mg(MgF)PO <sub>4</sub>   | IV.            | 3.1               | 5—5.5     |
| 7     | Warringtonite  | See Brochantite.   |                |                   |           |
| 8     | Wavellite      | 3 Al <sub>2</sub> O <sub>3</sub> .2 P <sub>2</sub> O <sub>5</sub> +<br>12 H <sub>2</sub> O   | IV.            | 2.33              | 3.5—4     |
| 9     | Websterite     | Al <sub>2</sub> SO <sub>4</sub> .9 H <sub>2</sub> O  | Am.            | 1.66              | Soft      |
| 10    | Wernerite      | See Scapolite.   |                |                   |           |
| 11    | White Arsenic  | See Arsenic, White   |                |                   |           |
| 12    | — Lead Ore     | See Cerussite.   |                |                   |           |
| 13    | — Nickel       | See Chloantite.  |                |                   |           |
| 14    | — Vitriol      | See Goslarite.   |                |                   |           |
| 15    | Willemite      | 2 ZnO.SiO <sub>2</sub>   | III. h.        | 4—4.1             | 5—5.5     |
| 16    | Witherite      | BaCO <sub>3</sub>  | IV.            | 4.29—4.35         | 3—3.75    |
| 17    | Wöhlerite      | 5 Na <sub>2</sub> O.20 CaO.<br>2Nb <sub>2</sub> O <sub>5</sub> .20 SiO <sub>2</sub> .3 ZrO <sub>3</sub><br>with other oxides<br>and F                            | V.             | 3.41              | 5—6       |
| 18    | Wolfram        | (Fe,Mn)WO <sub>4</sub>   | V.             | 7.1—7.9           | 5—5.5     |
| 19    | Wolframite     | See Tungstic Ochre.  |                |                   |           |
| 20    | Wollastonite   | CaO.SiO <sub>2</sub>   | V.             | 2.7—2.9           | 4.5—5     |
| 21    | Wood Opal      | SiO <sub>2</sub> replacing fibres  | of wood.       |                   |           |
| 22    | Woodwardite    | CuSO <sub>4</sub> .Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> .aq   |                |                   |           |
| 23    | Wulfenite      | PbMoO <sub>4</sub>   |                | 6.03—7.01         | 2.75—3    |
| 24    | Xanthophyllite | 4 H <sub>2</sub> O.14 (Mg,Ca)O.<br>8 (Al,Fe) <sub>2</sub> O <sub>3</sub> .5 SiO <sub>2</sub>   | II.<br>V.      | 3—3.1             | 4.5—5.    |
| 25    | Xenotime       | (Y,Ce,Er)PO <sub>4</sub>   |                | 4.45—4.55         | 4.5—5     |
| 26    | Yenite         | Lièpvreite (q.v)   | II.            |                   |           |
| 27    | Yttrialite     | Y <sub>2</sub> O <sub>3</sub> .2 SiO <sub>2</sub> .with Th,<br>Fe  |                | 4.57              | 5—5.6     |
| 28    | Yttrocerite    | (Y,Er,Ce)F <sub>3</sub> .5CaF <sub>2</sub> .<br>H <sub>2</sub> O   |                | 3.3—3.4           | 4—5       |
| 29    | Yttrotantalite | Y <sub>4</sub> (Ta <sub>2</sub> O <sub>7</sub> ) <sub>3</sub> contg. He  |                | 5.2—5.9           | 5.5       |
| 30    | Yttrotitanite  | CaO.TiO <sub>2</sub> .SiO <sub>2</sub> .<br>Y <sub>2</sub> AlFe <sub>2</sub> O <sub>3</sub> .SiO <sub>2</sub> .  | IV.<br>V.      | 3.51—3.72         | 6—7       |
| 31    | Zaratite       | See Emerald Nickel   |                |                   |           |
| 32    | Zincite        | ZnO.   |                | 5.68—5.74         | 4—4.5     |
| 33    | Zinkenite      | PbS.S <sub>2</sub> Sb <sub>2</sub>   | III.<br>IV.    | 5.30—5.35         | 2—2.5     |
| 34    | Zinnwaldite    | 4(Na,Li,K)F. 10 SiO <sub>2</sub> .<br>Fe <sub>2</sub> O <sub>3</sub> .3Al <sub>2</sub> O <sub>3</sub> .<br>(Na,Li,K) <sub>2</sub> O                              | V.             | 2.909             | 2—2.5     |
| 35    | Zippeite       | U <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> with <5%<br>CuO   | IV.            |                   |           |
| 36    | Zircon         | ZrSiO <sub>4</sub>   | II.            | 4.7               | 7.5       |

| Lustre.       | Colour.                                  | Streak.     | Fracture.                      | Fusibility. | Solubility.  |                                 |
|---------------|--|-------------|--------------------------------|-------------|--|---------------------------------|
| Py. vit.      | Y., G.<br>Bl.G.                          | Y.<br>G.Gr. | Earthy<br>Uneven               | Fus.        | s. HNO <sub>3</sub>  | 1<br>2                          |
| Py.           | Dirty-rose R.                            | P.          | Implanted<br>globules<br>Scaly |             |  | 4                               |
| Dull          | Bl., B., Gr., Br.                        | Gr.Br.      | Earthy                         | Inf.        | s. HCl   | 5                               |
| Vit.          | Y.—Gr                                    |             | Imperfect<br>conch.            | D. fus.     | Ins.   | 6                               |
| Vit. py. res. | W., Y., Br.                              | W.          | Brittle,                       | Inf.        | s. warm HCl  | 7<br>8                          |
| Dull          | W.                                       | W.          | spherular<br>Earthy            |             |  | 9<br>10<br>11<br>12<br>13<br>14 |
| Vit.          | W., Y., Br.                              | W.          | Conch.                         | Inf.        | Ins.   | 15                              |
| Vit. res.     | W., Y., Gr.                              | W.          | Brittle                        | Inf.        | s. ac.   | 16                              |
| Greasy        | Y., B., G.                               |             |                                | Fus.        | Decomp. HCl<br>with sepn. of<br>SiO <sub>2</sub> and<br>Nb <sub>2</sub> O <sub>5</sub> | 17                              |
| Met.—dull     | Gr.Bl.                                   | R.Br.       | Uneven                         | Fus.        | s. H <sub>2</sub> SO <sub>4</sub>  | 18<br>19                        |
| Vit. py.      | W., Gr., Y.,<br>P., Br.                  | W.          | Tough                          | 4           | Ins.   | 20<br>21<br>22                  |
| Wax. ad.      | Turquoise B.<br>Y., Or., Gr.,<br>W., Br. | W.          | Brittle                        | Fus.        | Decomp. HCl  | 23                              |
| Vit. py.      | Y., G., C.                               |             | oP                             | Inf.        | Decomp HCl<br>with sepn. of<br>SiO <sub>2</sub>  | 24                              |
| Greasy        | R.Br., Y.Br.,<br>R., Y.                  | Y.W., P.    | oP                             | Inf.        | Ins.   | 25<br>26<br>27<br>28            |
|               | Y., Y.Gr.                                |             |                                | Inf.        | E.s. HCl   |                                 |
|               | B.Gr., B.W.                              |             |                                |             |  |                                 |
| Met. vit.     | Bl., G.                                  | Gr.         | Conch.                         | Inf.        | Ins.   | 29                              |
| Vit.          | Br.R., Br.                               | Gr.Y.       |                                | Inf.        | s. HCl   | 30<br>31                        |
| Sub-ad.       | Bright R.                                | Or.Y.       | Laminated                      | Inf.        | s. HNO <sub>3</sub>  | 32                              |
| Met.          | Gr.                                      | Gr.         |                                | Fus.        | s. HNO <sub>3</sub> with<br>sepn. of S<br>and Sb <sub>2</sub> O <sub>3</sub>           | 33<br>34                        |
| Py.           | G.                                       | W.          | Micaceous                      | 1           |  |                                 |
|               | G.Y.                                     | Y.W.        |                                |             |  | 35                              |
| Ad.           | C., Gr., Y.,<br>G., R.Br.                | C.          | Conch.                         | Inf.        | Ins.   | 36                              |

## GENERAL PROPERTIES OF INORGANIC

If water of crystallisation in ( ),  
Salts of Organic Acids will be found

| Name.            | Formula.   | Density.        |                          |
|------------------|--|-----------------|--------------------------|
|                  |  | Formula Weight. | Water=1<br>D:Air=1       |
| 1 Alum, ammonium | $\text{Al}_2(\text{SO}_4)_3(\text{NH}_4)_2\text{SO}_4 + 24 \text{H}_2\text{O}$ | 907.1           | 1.6357/0°                |
| 2 — chrome       | $\text{Cr}_2(\text{SO}_4)_3\text{K}_2\text{SO}_4 + 24 \text{H}_2\text{O}$      | 998.9           | 1.83                     |
| 3 — iron         | $\text{Fe}_2(\text{SO}_4)_3(\text{NH}_4)_2\text{SO}_4 + 24 \text{H}_2\text{O}$ | 964.4           | 1.712                    |
| 4 — potash       | $\text{Al}_2(\text{SO}_4)_3\text{K}_2\text{SO}_4 + 24 \text{H}_2\text{O}$      | 948.9           | 1.751/17°                |
| 5 — silver       | $\text{Al}_2(\text{SO}_4)_3\text{Ag}_2\text{SO}_4 + 24 \text{H}_2\text{O}$     | 1086.5          |                          |
| 6 — sodium       | $\text{Al}_2(\text{SO}_4)_3\text{Na}_2\text{SO}_4 + 24 \text{H}_2\text{O}$     | 916.7           | 1.675/20°                |
| 7 Aluminium      | Al   | 27.0            | 2.583                    |
| 8 — bromide      | $\text{Al}_2\text{Br}_6 (+12 \text{H}_2\text{O})$                              | 533.5           | 2.54                     |
| 9 — carbide      | $\text{Al}_4\text{C}_3$  | 144.0           | 2.36                     |
| 10 — chloride    | $\text{Al}_2\text{Cl}_6 (+12 \text{H}_2\text{O})$                              | 266.8           | D:9.34/400°<br>4.51/835° |
| 11 — fluoride    | $\text{Al}_2\text{F}_6$  | 168.0           | 3.1                      |
| 12 — hydroxide   | $\text{Al}_2(\text{OH})_6$   | 156.0           | 2.23                     |
| 13 — iodide      | $\text{Al}_2\text{I}_6 (+12 \text{H}_2\text{O})$                               | 815.5           | 2.63                     |
| 14 — nitrate     | $\text{Al}_2(\text{NO}_3)_6 + 18 \text{H}_2\text{O}$                           | 750.4           |                          |
| 15 — nitride     | AlN  | 41.0            |                          |
| 16 — oxide       | $\text{Al}_2\text{O}_3$  | 102.0           | 3.75—4.0                 |
| 17 — phosphate   | $\text{Al}_2(\text{PO}_4)_2$   | 244.1           | 2.59                     |
| 18 — sulphate    | $\text{Al}_2(\text{SO}_4)_3$   | 342.2           | 2.74                     |
| 19 — sulphate    | $\text{Al}_2(\text{SO}_4)_3 + 18 \text{H}_2\text{O}$                           | 666.6           | 1.69                     |
| 20 — sulphide    | $\text{Al}_2\text{S}_3$  | 150.2           | 2.37                     |
| 21 Ammonia       | $\text{NH}_3$  | 17.03           | liq.:0.6234              |

Notes.—s. soluble; i. insoluble; v.s. very soluble; s.s. slightly soluble; v.s.s. very slightly soluble; m. miscible in all proportions; c. cold; h. hot; alc. alcohol; alk. alkalies; ac. acids; liq. liquid; gas. gaseous;  $>\text{H}_2\text{O}$ ,  $<\text{H}_2\text{O}$ , heavier, lighter than water; d. decomposed; an. anhydrous. In the fourth column, D. represents the density of the gaseous form. In column nine, the sign aq., 2aq., 3aq., with a temperature signifies that the compound loses 1, 2, or 3 molecules of



**COMPOUNDS.** (See also "Properties of Minerals.")  
 not included in formula weight.  
 in the Tables of Organic Compounds.

| Crystalline form and colour | Solubility*in                  |                                  | Alcohol, acids or alkalies                      | M.P. °C.   | B.P. °C.             |    |
|-----------------------------|--------------------------------|----------------------------------|---|--|----------------------|----|
|                             | 100 parts water at 15°C (60°F) | 100 parts water at 100°C (212°F) |   |  |                      |    |
| L. C.                       | 11.4                           | 421.9                            | i. alc.   |  |                      | 1  |
| L. R.                       | 15                             | green at 70°                     | i. alc.   | 22aq 200<br>24aq 400   |                      | 2  |
| L. Viol.                    | 14.3(20°)                      | 400                              | i. alc.   | 24aq 230   |                      | 3  |
| L. O.                       | 9.6                            | 357.5                            |   | 84.5   | 18aq 60<br>24aq R.H. | 4  |
|                             | d.                             |                                  |   |  |                      | 5  |
| L.                          | 110                            | v.s.                             | i. alc.   | 24aq 50  |                      | 6  |
| B.W.                        | i.                             | i.                               | s. alk., HCl,<br>H <sub>2</sub> SO <sub>4</sub> | 658.7  |                      | 7  |
| O.                          | s.                             | s.                               | s. alc., CS <sub>2</sub>                        | 93   | 263                  | 8  |
| G. cryst.                   | gives CH <sub>4</sub>          |                                  |   |  |                      | 9  |
| III.                        | s.                             | loses HCl                        | s. alc.   |  | 182/752 mm.          | 10 |
| IIIa. C.                    | an. i.<br>+7aq. s.             |                                  | i. alc., alk., ac.                              |  |                      | 11 |
| Am. W.                      | i.                             | i.                               | s. ac., alk.                                    | at 300 :<br>Al <sub>2</sub> O <sub>3</sub> ·H <sub>2</sub> O |                      | 12 |
| W.                          | an. i.,<br>+12aq. s.           |                                  | s. alc., CS <sub>2</sub>                        | 185  | 360                  | 13 |
|                             | v.s.                           | v.s.                             | s. alc.   | 73   | d. 134               | 14 |
| Y. cryst.                   | d.                             |                                  |   | d. 135   |                      | 15 |
| III. Am.                    | i.                             | i.                               | s. H <sub>2</sub> SO <sub>4</sub>               |  |                      | 16 |
| III. C.                     | i.                             | i.                               | s. alk., ac.,<br>i. acetic                      |  |                      | 17 |
| W.                          | 35                             | 89.1                             | s.s. alc.                                       |  |                      | 18 |
| V. O.                       | 102                            | 1132                             |   |  |                      | 19 |
| Y. cryst.                   | d.                             |                                  |   | d.   |                      | 20 |
|                             | 597 vols.                      | i.                               | v.s. alc.                                       | - 75   | 33.5                 | 21 |

water at that temperature. R.H. red heat; W.H. white heat; C. colourless; W. white; R. red; P. pink; B. blue; Y. yellow; G. green; Br. brown; Bl. black; Gr. grey; Viol. violet; L. lilac; Or. orange; expl. explodes; diss. dissociates.

Crystal forms (see "Crystallography" section): I. cubic; II. tetragonal; III. hexagonal; IIIa. rhombohedral; IV. rhombic; V. monoclinic; VI. triclinic; Am. amorphous.

\* Parts anhydrous substance unless otherwise stated.

| Name.                   | Formula.  | Density.        |                         |
|-------------------------|---|-----------------|-------------------------|
|                         |   | Formula Weight. | Water=1<br>D:Air=1      |
| 1 Ammonium aurichloride | $\text{NH}_4\text{AuCl}_4$  | 357.1           |                         |
| 2 — auricyanide         | $\text{Au}(\text{CN})_3\text{NH}_4\text{CN} + \text{H}_2\text{O}$             | 337.3           |                         |
| 3 — aurocyanide         | $\text{Au}(\text{CN})_2\text{NH}_4\text{CN}$                                  | 293.3           |                         |
| 4 — bicarbonate         | $\text{NH}_4\text{HCO}_3$   | 79.05           | 1.586                   |
| 5 — borofluoride        | $\text{NH}_4\text{BF}_4$  | 105.0           | 1.851/17°               |
| 6 — bromide             | $\text{NH}_4\text{Br}$  | 97.96           | 2.379/4°<br>D:1.67/440° |
| 7 — carbamate           | $\text{NH}_4\text{HCO}_3 + \text{NH}_4\text{CO}_2\text{NH}_2$                 | 157.12          |                         |
| 8 — carbonate           | $(\text{NH}_4)_2\text{CO}_3 + \text{H}_2\text{O}$                             | 114.1           |                         |
| 9 — chlorate            | $\text{NH}_4\text{ClO}_3$   | 101.50          |                         |
| 10 — chloride           | $\text{NH}_4\text{Cl}$  | 53.50           | 1.532                   |
| 11 — chromate           | $(\text{NH}_4)_2\text{CrO}_4$   | 152.08          | 1.886/11°               |
| 12 — chromic sulphate   | $\text{Cr}_2(\text{SO}_4)_3(\text{NH}_4)_2\text{SO}_4 + 24\text{H}_2\text{O}$ | 956.71          | 1.736/21°               |
| 13 — cyanate            | $\text{NH}_4\text{CNO}$   | 60.06           |                         |
| 14 — cyanide            | $\text{NH}_4\text{CN}$  | 44.06           | D:0.79/100°             |
| 15 — dichromate         | $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$  | 252.08          | 2.367                   |
| 16 — ferricyanide       | $2(\text{NH}_4)_3\text{Fe}(\text{CN})_6 + \text{H}_2\text{O}$                 | 550.05          |                         |
| 17 — ferrocyanide       | $(\text{NH}_4)_4\text{Fe}(\text{CN})_6 + 3\text{H}_2\text{O}$                 | 338.2           |                         |
| 18 — fluoride           | $\text{NH}_4\text{F}$   | 37.0            |                         |
| 19 — hydrogen fluoride  | $\text{NH}_4\text{F} \cdot \text{HF}$   | 57.0            | 1.210/12°               |
| 20 — — phosphate        | $(\text{NH}_4)_2\text{HPO}_4$   | 132.13          | 1.803/20°               |
| 21 — — sulphide         | $\text{NH}_4\text{HS}$  | 51.11           |                         |
| 22 — hypophosphite      | $\text{NH}_4\text{H}_2\text{PO}_2$  | 83.10           | 2.515                   |
| 23 — iodide             | $\text{NH}_4\text{I}$   | 144.96          | D:2.51/440°             |
| 24 — iridichloride      | $(\text{NH}_4)_2\text{IrCl}_6$  | 456.0           |                         |
| 25 — magnesium arsenate | $\text{Mg}(\text{NH}_4)\text{AsO}_4 + 6\text{H}_2\text{O}$                    | 289.42          |                         |
| 26 — — phosphate        | $\text{Mg}(\text{NH}_4)\text{PO}_4 + 6\text{H}_2\text{O}$                     | 245.5           | 1.65                    |
| 27 — molybdate          | $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24} + 4\text{H}_2\text{O}$               | 1236.3          | 2.498                   |
| 28 — nitrate            | $\text{NH}_4\text{NO}_3$  | 80.05           | 1.72/15°                |
| 29 — nitrite            | $\text{NH}_4\text{NO}_2$  | 64.05           | 1.69                    |
| 30 — palladichloride    | $(\text{NH}_4)_2\text{PdCl}_6$  | 355.5           | 2.418                   |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       | Alcohol,<br>acids<br>or alkalies | M.P.<br>°C.                   | B.P.<br>°C. |    |
|-----------------------------------|-------------------------------------|---------------------------------------|----------------------------------|-------------------------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) |                                  |                               |             |    |
|                                   | v.s.                                | v.s.                                  |                                  | an. at 100                    |             | 1  |
| Plates                            | s.                                  |                                       | s. alk.                          | d.                            |             | 2  |
| C.                                | s.                                  |                                       | s. alk.                          | d. 150—200                    |             | 3  |
| IV. W.                            | 18.5                                | d.                                    | i. alc.                          | d. 60                         |             | 4  |
| III. prism                        | 25                                  | 100                                   | s. alk.                          |                               |             | 5  |
| I. C.                             | 66                                  | 128                                   | s.s. alc.                        | d.                            |             | 6  |
| W. cryst.                         | 25                                  | 70 (65°)                              | d. by alc.                       |                               | subl.       | 7  |
| C.                                | 100                                 | d. 70—75°                             | s. alc.                          | d. 85°                        |             | 8  |
| V.                                | s.                                  | s.                                    | v.s.s. alc.                      | expl. 102                     |             | 9  |
| I. or II. C                       | 35.2                                | 77.3                                  | v.s.s. alc.                      |                               | diss. 350   | 10 |
| V. Y.                             | 40.5/30°                            | d.                                    |                                  | d.                            |             | 11 |
| I. Oct.                           | 12.1                                | green at 70°                          |                                  | 18aq 100                      |             | 12 |
|                                   |                                     |                                       |                                  | 22aq > 100                    |             |    |
|                                   | s.                                  | d.                                    | s.s. alc.                        | d.                            |             | 13 |
| I. C.                             | s.                                  | d.                                    | s. alc.                          |                               | diss. 36    | 14 |
| V. G.R.                           | 47.2/30°                            | v.s.                                  |                                  | d. to $\text{Cr}_2\text{O}_3$ |             | 15 |
| R. prism.                         | s.                                  | s.                                    |                                  |                               |             | 16 |
| Y. prism.                         | v.s.                                | d.                                    | i. alc.                          |                               |             | 17 |
| III. C.                           | deliq.                              | v.s.                                  | s.s. alc.                        |                               | subl.       | 18 |
| IV. C.                            | deliq.                              | v.s.                                  |                                  |                               | diss.       | 19 |
| V. C.                             | 25                                  | s.                                    | i. alc.                          |                               |             | 20 |
| IV. C.                            | s.                                  | s.                                    | s. alc.                          | subl.                         |             | 21 |
|                                   | 128.1 (0°)                          |                                       |                                  |                               |             |    |
| III. W.<br>plates                 | s.                                  | s.                                    | v.s. alc.                        | 200                           | d. 240      | 22 |
| I.                                | deliq. 167                          | v.s.                                  | s. alc.                          |                               |             | 23 |
| R. pdr.                           | 0.699                               | 1.266 (39°)                           |                                  |                               |             | 24 |
| II.                               | 0.17                                | i.                                    | i. alc.                          |                               |             | 25 |
| II.                               | 0.005                               | i.                                    | i. alc.                          |                               |             | 26 |
| IV. C.                            | 40                                  | s.                                    |                                  | d.                            |             | 27 |
| IV.                               | 106                                 | v.s.                                  | s. in 67% alc.                   | 152                           | d. 210      | 28 |
| W.                                | v.s.                                | d. 50°                                |                                  | d.                            |             | 29 |
| I. R.                             | s.s.                                | s.s.                                  |                                  |                               |             | 30 |

| Name.                   | Formula.   | Density         |                                    |
|-------------------------|--|-----------------|------------------------------------|
|                         |  | Formula Weight. | Water=1<br>Air=1                   |
| 1 Ammonium perchlorate  | $\text{NH}_4\text{ClO}_4$  | 117.50          | 1.87                               |
| 2 — permanganate        | $\text{NH}_4\text{MnO}_4$  | 136.97          |                                    |
| 3 — persulphate         | $(\text{NH}_4)_2\text{S}_2\text{O}_8$                                      | 228.20          |                                    |
| 4 — phosphomolybdate    | $(\text{NH}_4)_3\text{PO}_4 \cdot 10\text{MoO}_3 + 3\text{H}_2\text{O}$    | 1643.2          |                                    |
| 5 — platinibromide      | $(\text{NH}_4)_2\text{PtBr}_6$   | 710.8           | 4.2                                |
| 6 — platinichloride     | $(\text{NH}_4)_2\text{PtCl}_6$   | 444.0           | 3.065                              |
| 7 — sequicarbonate      | $2\text{NH}_4\text{HCO}_3 (\text{NH}_4)_2\text{CO}_3 + \text{H}_2\text{O}$ | 272.2           |                                    |
| 8 — stannichloride      | $(\text{NH}_4)_2\text{SnCl}_6$   | 367.5           |                                    |
| 9 — sulphate            | $(\text{NH}_4)_2\text{SO}_4$   | 132.14          | 1.77/20°                           |
| 10 — sulphide           | $(\text{NH}_4)_2\text{S}$  | 68.14           |                                    |
| 11 — sulphite           | $(\text{NH}_4)_2\text{SO}_3$   | 116.14          |                                    |
| 12 — thiocyanate        | $\text{NH}_4\text{CNS}$  | 76.12           | 1.3057/13°                         |
| 13 Antimonic acid       | $\text{HSbO}_3$  | 169.2           | 6.6                                |
| 14 Antimonious acid     | $\text{HSbO}_2$  | 153.2           |                                    |
| 15 Antimony             | $\text{Sb}$  | 120.2           | 6.62                               |
| 16 — chloride (basio)   | $2\text{SbOCl}; \text{Sb}_2\text{O}_3$                                     | 631.7           |                                    |
| 17 — hydride (stibine)  | $\text{SbH}_3$   | 123.2           | D : 4.36/15°                       |
| 18 Antimonyl sulphate   | $(\text{SbO})_2\text{SO}_4$  | 368.5           | 4.89                               |
| 19 — — (basio)          | $(\text{SbO})_2\text{Sb}_2(\text{OH})_4\text{SO}_4$                        | 676.9           |                                    |
| 20 Antimony oxychloride | $\text{SbOCl}_3$   | 242.6           |                                    |
| 21 — oxychloride        | $\text{SbOCl}$   | 171.7           |                                    |
| 22 — pentachloride      | $\text{SbCl}_5$  | 297.5           | 2.316                              |
| 23 — pentafluoride      | $\text{SbF}_5$   | 215.2           | 2.993/23°                          |
| 24 — pentasulphide      | $\text{Sb}_2\text{S}_5$  | 400.8           | 4.12/0°                            |
| 25 — pentiodide         | $\text{SbI}_5$   | 754.8           |                                    |
| 26 — pentoxide          | $\text{Sb}_2\text{O}_5$  | 320.4           | 3.8                                |
| 27 — sulphate           | $\text{Sb}_2(\text{SO}_4)_3$   | 528.6           |                                    |
| 28 — tetroxide          | $\text{Sb}_2\text{O}_4$  | 304.4           | 4.07                               |
| 29 — tribromide         | $\text{SbBr}_3$  | 360.0           | 4.148/23°;                         |
| 30 — trichloride        | $\text{SbCl}_3$  | 228.6           | D : 7.96, 3.06/<br>26°<br>2.67/72° |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       | Alcohol,<br>acids<br>or alkalies               | M.P.<br>°C.             | B.P.<br>°C.                    |    |
|-----------------------------------|-------------------------------------|---------------------------------------|--|-------------------------|--------------------------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) |  |                         |                                |    |
| IV. —                             | 20                                  |                                       | s.s. alo.                                      | d.                      |                                | 1  |
| Needles                           | 8.0                                 |                                       |  | slowly<br>heated—<br>d. | rapidly<br>heated—<br>expl. d. | 2  |
| V.                                | 58.2 (0°)                           | d.                                    |  |                         |                                | 3  |
| Y.                                | 0.03                                |                                       | i. alo.  |                         |                                | 4  |
| I. Oct.                           | 0.5                                 |                                       |  | d.                      |                                | 5  |
| Y.                                | 0.67                                | 12.5                                  |  | d.                      |                                | 6  |
| IV.                               | 20                                  | d.                                    |  | d.                      |                                | 7  |
| I. P.                             | 33.3                                | s.                                    |  |                         |                                | 8  |
| IV. C.                            | 74.2                                | 103.3                                 | i. alo.  | d. 140                  |                                | 9  |
|                                   | v.s.                                |                                       |  | d.                      |                                | 10 |
| V.                                | 100 (12°)                           |                                       | i. alo.  | d.                      |                                | 11 |
| V. C.                             | 162.2 (20°)                         |                                       | s. alc.  | 149.5                   | d. 170                         | 12 |
| W.                                | s.s.                                | s.s.                                  | s. ac., s. KOH                                 |                         |                                | 13 |
|                                   | i.                                  | i.                                    | i. alo.  | d.                      |                                | 14 |
| IIIa. W.                          |                                     |                                       | s.h. HCl,<br>s. H <sub>2</sub> SO <sub>4</sub> | 630.0                   | R.H.                           | 15 |
| III. W.                           | i.                                  |                                       |  | d.                      |                                | 16 |
| W.                                | 20 vol.                             |                                       | 1500 vol. in<br>alc.                           | -91.5                   | -18                            | 17 |
| W.                                | d.                                  |                                       |  |                         |                                | 18 |
| W.                                | i.                                  | d.                                    |  |                         |                                | 19 |
| Y.                                | d.                                  |                                       | s. alc.  |                         |                                | 20 |
| I., IIIa.                         | i.                                  | d.                                    | i. alc.,<br>s. HCl, CS <sub>2</sub>            | d.                      | d.                             | 21 |
| V. W.                             | d.                                  |                                       |  | -6                      | 102/68 mm.                     | 22 |
|                                   | s.                                  |                                       | s. KF soln.                                    |                         | 155                            | 23 |
| Or.                               | i.                                  | i.                                    | s. NH <sub>4</sub> HS                          | d.                      |                                | 24 |
| Br.                               |                                     |                                       |  |                         | 78—79                          | 25 |
| Y.W.                              | v.s.s.                              | i.                                    | s. HCl,<br>s.s. KOH                            | d. 300                  |                                | 26 |
| W. needle                         | d.                                  |                                       |  |                         |                                | 27 |
| W.                                | i.                                  | i.                                    | s. alk., s.s. ac.                              | infusible               |                                | 28 |
| IV. C.                            | d.                                  |                                       |  | 93                      | 280                            | 29 |
| IV. C.                            | s., quickly<br>d.                   |                                       | s. conc. HCl,<br>s. alc.                       | 73.2                    | 223                            | 30 |

| Name.                  | Formula.  | Density.        |  |
|------------------------|---|-----------------|--|
|                        |   | Formula Weight. | Water=1<br>D:Air=1                         |
| 1 Antimony trifluoride | $\text{SbF}_3$                                  | 177.2           |  |
| 2 —, sodium sulphate   | $\text{SbF}_3, \text{Na}_2\text{SO}_4$          | 319.3           |  |
| 3 — tri-iodide         | $\text{SbI}_3$                                  | 501.0           | (1) 4.85/26°<br>(2) D:17.6<br>(3) 4.77/22° |
| 4 — trioxide           | $\text{Sb}_2\text{O}_3$                         | 288.4           | 5.556 nat.;<br>5.2 (1)                     |
| 5 — trisulphide        | $\text{Sb}_2\text{S}_3$                         | 336.6           | (1) 4.65<br>(2) 4.15                       |
| 6 Argon                | A   | 39.88           |  |
| 7 Arsenic, cryst.      | As  | 74.96           | 5.73/14°                                   |
| 8 — amorph.            | As  | 74.96           | 4.71                                       |
| 9 — acid, ortho-       | $2\text{AsO}(\text{OH})_3 + \text{H}_2\text{O}$ | 301.98          | 2—2.5 gas.                                 |
| 10 — — pyro-           | $\text{As}_2\text{O}_3(\text{OH})_4$            | 265.95          |  |
| 11 — — meta-           | $\text{AsO}_2.\text{OH}$                        | 123.97          |  |
| 12 — di-iodide         | $\text{As}_2\text{I}_4$                         | 657.60          |  |
| 13 — disulphide        | $\text{As}_2\text{S}_2$                         | 214.04          | 3.54                                       |
| 14 — hydride (arsine)  | $\text{AsH}_3$                                  | 77.98           |  |
| 15 — — (solid)         | $\text{As}_2\text{H}_2$                         | 151.94          |  |
| 16 — oxychloride       | $\text{AsOCl}$                                  | 126.42          |  |
| 17 — pentasulphide     | $\text{As}_2\text{S}_5$                         | 310.20          |  |
| 18 — pentoxide         | $\text{As}_2\text{O}_5$                         | 229.92          | 3.754                                      |
| 19 — phosphide         | $\text{AsP}$                                    | 106.00          |  |
| 20 — selenide          | $\text{As}_2\text{Se}_3$                        | 387.51          | 4.75                                       |
| 21 — tribromide        | $\text{AsBr}_3$                                 | 314.72          | 3.7/15°                                    |
| 22 — trichloride       | $\text{AsCl}_3$                                 | 181.34          | 2.205/0°                                   |
| 23 — trifluoride       | $\text{AsF}_3$                                  | 131.96          | 2.666                                      |
| 24 — tri-iodide        | $\text{AsI}_3$                                  | 455.72          | 4.4/13°                                    |
| 25 — trisulphide       | $\text{As}_2\text{S}_3$                         | 246.10          | 3.46;<br>amorph. 2.76                      |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       |  | M.P.<br>°C.       | B.P.<br>°C. |    |
|-----------------------------------|-------------------------------------|---------------------------------------|--|-------------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) | Alcohol,<br>acids<br>or alkalies                       |                   |             |    |
|                                   | s., d.                              |                                       |  | 292               |             | 1  |
|                                   | s.                                  | s.                                    |  |                   |             | 2  |
| (1) III. R                        | d.                                  |                                       | s. alc., CS <sub>2</sub> ,                             | 167               | 401         | 3  |
| (2) IV. Y.                        |                                     |                                       | HCl  | subl. 114         |             |    |
| (3) V. R.                         |                                     |                                       |  |                   |             |    |
| IV., l.                           | i.                                  |                                       | s. conc. HCl,<br>tartaric acid                         | R.H.              | subl. 1550  | 4  |
| (1) III. Bl                       | i.                                  | i.                                    | s. am. sulph.  | 555               | diss.       | 5  |
| (2)-Am. Br                        |                                     |                                       |  |                   |             |    |
|                                   | 4 (20°)                             |                                       |  | -189.6            | -186.1      | 6  |
| Gr.Bl.                            | i.                                  | i.                                    | s. ac.   | subl. 450         |             | 7  |
| Y. vapour                         | i.                                  | i.                                    | s. CS <sub>2</sub>                                     | subl.             |             | 8  |
| W. cryst.                         | 16.7                                | 50                                    |  | aq 180            |             | 9  |
|                                   | becomes<br>ortho                    |                                       |  | d. 206 to<br>meta |             | 10 |
|                                   | becomes<br>ortho                    |                                       |  | d. R.H.           |             | 11 |
| R. prism                          |                                     | d.                                    | s. alc., ether,<br>CS <sub>2</sub> , CHCl <sub>3</sub> |                   |             | 12 |
| V. R.                             | i.                                  | i.                                    | s. KHS,<br>NaHCO <sub>3</sub>                          | fusible           |             | 13 |
|                                   | 5 vols.                             | s.s.                                  | s.s. alc.  | -113              | -54.8       | 14 |
| Br.                               | i.                                  |                                       |  | d. 200            |             | 15 |
| Br.                               | d.                                  |                                       |  | fusible           | d.          | 16 |
| Y.                                | i.                                  | i.                                    | s. alc.  | fusible           | subl.       | 17 |
| Am. W.                            | 245                                 | v.s.                                  | v.s.   | R.H.              | d.          | 18 |
| Br.R. pdr.                        | d.                                  |                                       | i. ac., alc.   | d.                | d.          | 19 |
| C. cryst.                         | i.                                  | d.                                    | s. alk.  | 360               |             | 20 |
|                                   | d.                                  |                                       | s. HCl   | 31                | 221/745     | 21 |
|                                   | s., rapid d                         |                                       | s. HCl, alc.   | liq. - 18         | 130.2       | 22 |
|                                   | d.                                  |                                       | s. NH <sub>3</sub> soln.                               | -8.5              | 60.4        | 23 |
| IIIa. Y.                          | s.                                  | i.                                    | s. alc., ether   | subl. 146         | 394-414     | 24 |
| Y                                 | i.                                  | i.                                    | s. alc.  |                   | >700        | 25 |

| Name.                   | Formula.   | Density.        |                                |
|-------------------------|--|-----------------|--------------------------------|
|                         |  | Formula Weight. | Water=1<br>D:Air=1             |
| 1 Arsenious oxide       | $\text{As}_2\text{O}_3$                                    | 197.92          | cryst. 3.699;<br>amorph. 3.738 |
| 2 Auric chloride        | $\text{AuCl}_3$  | 303.6           | 3.9                            |
| 3 — cyanide             | $\text{Au}(\text{CN})_3 + 3 \text{H}_2\text{O}$            | 329.3           |                                |
| 4 — hydroxide           | $\text{Au}(\text{OH})_3$                                   | 248.2           |                                |
| 5 — oxide               | $\text{Au}_2\text{O}_3$                                    | 442.4           |                                |
| 6 Auro-auric sulphide   | $\text{Au}_2\text{S}_2$                                    | 458.5           |                                |
| 7 Aurous bromide        | $\text{AuBr}_3$  | 277.1           |                                |
| 8 — chloride            | $\text{AuCl}_3$  | 232.7           |                                |
| 9 — cyanide             | $\text{AuCN}$  | 223.2           |                                |
| 10 — hydroxide          | $\text{AuOH}$  | 214.2           |                                |
| 11 — iodide             | $\text{AuI}$   | 324.1           |                                |
| 12 — oxide              | $\text{Au}_2\text{O}$                                      | 410.4           | 3.6                            |
| 13 — — sulphide         | $\text{Au}_2\text{S}$                                      | 426.5           |                                |
| 14 Azoimide             | $\text{N}_3\text{H}$                                       | 43.04           |                                |
| 15 Barium               | $\text{Ba}$  | 137.37          | 3.78                           |
| 16 — bromate            | $\text{Ba}(\text{BrO}_3)_2 (+ \text{H}_2\text{O})$         | 393.21          | 4.04/17°                       |
| 17 — bromide            | $\text{BaBr}_2 + 2 \text{H}_2\text{O}$                     | 333.24          | 3.85/24°                       |
| 18 — carbide            | $\text{BaC}_2$   | 161.38          | 3.75                           |
| 19 — carbonate          | $\text{BaCO}_3$  | 197.37          | 4.275                          |
| 20 — chlorate           | $\text{Ba}(\text{ClO}_3)_2 + \text{H}_2\text{O}$           | 322.31          | 3.179                          |
| 21 — chloride           | $\text{BaCl}_2 + 2 \text{H}_2\text{O}$                     | 244.32          | 3.1/24°                        |
| 22 — chromate           | $\text{BaCrO}_4$   | 253.4           | 3.9                            |
| 23 — dithionate         | $\text{BaS}_2\text{O}_6 + 2 \text{H}_2\text{O}$            | 333.52          | 4.536/13.5°                    |
| 24 — ferrocyanide       | $\text{Ba}_2\text{Fe}(\text{CN})_6 + 6 \text{H}_2\text{O}$ | 594.77          |                                |
| 25 — fluoride           | $\text{BaF}_2$   | 175.4           | ppd. 4.828                     |
| 26 — hydride            | $\text{BaH}_2$   | 139.39          | 4.21/0°                        |
| 27 — hydrogen phosphate | $\text{BaHPO}_4$   | 233.42          | 4.165                          |
| 28 — — sulphide         | $\text{Ba}(\text{HS})_2 (+ 4 \text{H}_2\text{O})$          | 203.51          |                                |



| Crystalline<br>form and<br>colour | Solubility*in                       |                                       | Alcohol,<br>acids<br>or alkalies | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------------------|-------------------------------------|---------------------------------------|----------------------------------|-------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) |                                  |             |             |    |
| Am., I.; W                        | 1.7                                 | 9.5                                   | s. HCl.                          | subl. 218   |             | 1  |
| Y.R.                              | 68                                  | s.                                    | s. alc.                          | subl.       | d. 180      | 2  |
| O. plates                         | v.s.                                | d.                                    |                                  | 50          | d.          | 3  |
| Y.Br.                             | i.                                  | i.                                    | s. HNO <sub>3</sub>              | d.          |             | 4  |
| Bl.                               | i.                                  | i.                                    | s. HCl                           | d. >100     |             | 5  |
| Bl.                               | i.                                  | i.                                    | s. am. sulph.                    | d.          |             | 6  |
| G.                                | i.                                  |                                       | d. ac.                           | d. >150     |             | 7  |
| Y.                                | d.                                  |                                       |                                  | d.          |             | 8  |
| Y.                                | i.                                  | i.                                    | i. alc., s. KCN                  | d.          |             | 9  |
| R.B.                              | s. —blue                            |                                       |                                  | d. 250      |             | 10 |
| Y.                                | i.                                  | d.                                    |                                  | d. <120     |             | 11 |
| Br.Bl.                            | i.                                  | i.                                    | s. HCl                           | d. 250      |             | 12 |
| Dark pdr.                         | an. i.                              |                                       | s. KCN                           |             |             | 13 |
| C.                                | m.                                  | m.                                    | s. alc., alk.                    | liq.        | 37          | 14 |
| W.                                | d.                                  |                                       |                                  | 850         | 1000        | 15 |
| V. O. cryst                       | 0.7                                 | 5.4                                   |                                  | d. 260      |             | 16 |
| IV.                               | 103                                 | 204                                   | s. alc.                          | 880         |             | 17 |
|                                   |                                     |                                       |                                  | 2 aq, 120   |             |    |
| Bl. cryst.                        | gives<br>acetylene                  |                                       |                                  |             |             | 18 |
| IV. W.                            | i.                                  | i.                                    | i. alc                           | 795         | d. 1450     | 19 |
| V.                                | 33.4                                | 126                                   | s.s. alc.                        | an. 414     | (+aq 120)   | 20 |
| IV.                               | 34.5                                | 58.8                                  | i. alc., s.s.                    | 2aq, 113    |             | 21 |
|                                   |                                     |                                       | HCl, HNO <sub>3</sub>            | 960         |             |    |
| Y.                                | i.                                  | i.                                    | s. ac.                           |             |             | 22 |
| IV.                               | 24                                  | 90.9                                  |                                  | d.          |             | 23 |
| Prism.                            | 0.17                                | 0.9                                   |                                  |             |             | 24 |
| Am., W.                           | v.s.s.                              |                                       | s. NH <sub>4</sub> Cl;<br>s. HF  | 1280        |             | 25 |
| Gr.                               | d.                                  |                                       |                                  | abt. 1200   | 1400        | 26 |
| IV.                               | i.                                  | i.                                    | s. ac., s. NH <sub>4</sub> Cl    |             |             | 27 |
| IV.                               | s.                                  | s.                                    | i. alc.                          | d. 50       |             | 28 |

| Name.                           | Formula.  | Density.        |                    |
|---------------------------------|---|-----------------|--------------------|
|                                 |   | Formula Weight. | Water=1<br>D:Air=1 |
| 1 Barium hydroxide              | $\text{Ba}(\text{OH})_2 + 8 \text{H}_2\text{O}$           | 315.52          | an. 4.495          |
| 2 — hypophosphite               | $\text{Ba}(\text{H}_2\text{PO}_2)_2 + \text{H}_2\text{O}$ | 285.50          | 2.89/17°           |
| 3 — iodate                      | $\text{Ba}(\text{IO}_3)_2$                                | 487.21          | 4.998              |
| 4 — iodide                      | $\text{BaI}_2 + 2 \text{H}_2\text{O}$                     | 427.24          | an. 4.917          |
| 5 — manganate                   | $\text{BaMnO}_4$  | 256.3           | 4.85               |
| 6 — monoxide                    | $\text{BaO}$  | 153.37          | 4.7—5.5            |
| 7 — nitrate                     | $\text{Ba}(\text{NO}_3)_2$                                | 261.39          | 3.24/23°           |
| 8 — nitrite                     | $\text{Ba}(\text{NO}_2)_2$                                | 229.39          |                    |
| 9 — perchlorate                 | $\text{Ba}(\text{ClO}_4)_2$                               | 336.29          |                    |
| 10 — peroxide                   | $\text{BaO}_2$  | 169.37          | 4.958              |
| 11 — — (hydrate)                | $\text{BaO}_2 + 8 \text{H}_2\text{O}$                     | 313.50          |                    |
| 12 — persulphate                | $\text{Ba}(\text{SO}_4)_2 + 4 \text{H}_2\text{O}$         | 401.55          |                    |
| 13 — phosphate, ortho           | $\text{Ba}_3(\text{PO}_4)_2$                              | 602.19          | 4.1                |
| 14 — —, pyro                    | $\text{Ba}_2\text{P}_2\text{O}_7$                         | 448.82          | 3.9/20°            |
| 15 — platinichloride            | $\text{BaPtCl}_6 + 4 \text{H}_2\text{O}$                  | 617.4           | 2.86/8°            |
| 16 — platinocyanide             | $\text{BaPt}(\text{CN})_6 + 4 \text{H}_2\text{O}$         | 560.7           | 3.05               |
| 17 — silicofluoride             | $\text{BaSiF}_6$  | 279.5           | 4.29/21°           |
| 18 — sulphate                   | $\text{BaSO}_4$   | 233.43          | 4.486—4.53         |
| 19 — sulphide                   | $\text{BaS}$  | 169.43          | 4.30               |
| 20 — sulphite                   | $\text{BaSO}_3$   | 217.43          |                    |
| 21 — tetrahydrogen<br>phosphate | $\text{BaH}_4(\text{PO}_4)_2$                             | 331.48          | 2.9/4°             |
| 22 — tetrasulphide              | $\text{BaS}_4$  | 265.61          | 2.98/20°           |
| 23 Bismuth                      | $\text{Bi}$   | 209.0           | 9.76               |
| 24 — carbonate, basic           | $2(\text{BiO})_2\text{CO}_3 + \text{H}_2\text{O}$         | 1036.0          |                    |
| 25 — hydroxide                  | $\text{Bi}(\text{OH})_3$                                  | 260.0           |                    |
| 26 — iodate                     | $\text{Bi}(\text{IO}_3)_3$                                | 733.8           |                    |
| 27 — nitrate                    | $\text{Bi}(\text{NO}_3)_3 + 5 \text{H}_2\text{O}$         | 485.1           | 2.8                |
| 28 — — (basic)                  | $\text{Bi}(\text{OH})_2\text{NO}_3$                       | 305.0           |                    |
| 29 — oxychloride                | $\text{BiOCl}$  | 260.5           | 7.717/15°          |
| 30 — pentoxide                  | $\text{Bi}_2\text{O}_5$                                   | 498.0           |                    |
| 31 — phosphate                  | $\text{BiPO}_4$   | 304.0           | 6.323/15°          |
| 32 — sulphate                   | $\text{Bi}_2(\text{SO}_4)_3$                              | 706.2           |                    |

| Crystalline<br>form and<br>colour | Solubility*in                        |  | Alcohol,<br>acids<br>or alkalies | M.P.<br>°C.                            | B.P.<br>°C.                        |    |
|-----------------------------------|--------------------------------------|--|----------------------------------|--|------------------------------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) |                                  |  |                                    |    |
| II. W.                            | 3.3                                  | 101.5 (80°)                            | v.s.s. alc.                      | loses 7 aq.<br>in air<br>1 aq. at R.H. |                                    | 1  |
| V.                                | 30                                   | 33                                     | i. alc.                          | d.                                     |                                    | 2  |
| V.                                | .022                                 | 0.197                                  | s. $\text{HNO}_3$ , HCl          | d.                                     |                                    | 3  |
| IV.                               | 200                                  | 300                                    | v.s.                             | 740                                    |                                    | 4  |
| III., G.                          | i.                                   |  | s. ac.                           |  |                                    | 5  |
| Am., I.                           | combines                             |  | s. ac.                           | W.H.                                   |                                    | 6  |
| Gr.                               | with $\text{H}_2\text{O}$            |  |                                  |  |                                    |    |
| I.                                | 8.1                                  | 32.2                                   | i. alc.                          | 575                                    |                                    | 7  |
| III. Pyr.                         | 63/20°                               | v.s.                                   | v.s. HCl, s.<br>alc.             | d. 115                                 |                                    | 8  |
| III.                              | s.                                   |  | s. alc.                          | 505                                    |                                    | 9  |
| Gr.                               | i.                                   | d.                                     | s. HCl                           | R.H.                                   |                                    | 10 |
| III.                              | v.s.s.                               | d.                                     |                                  | 6 aq. : 130                            |                                    | 11 |
| V.                                | v.s.                                 | d.                                     |                                  |  |                                    | 12 |
|                                   | i.                                   | i.                                     | s. ac.                           |  |                                    | 13 |
| IV. W.                            | s.s.                                 | s.s.                                   | s. ac.                           |  |                                    | 14 |
| V. P.                             |                                      |  | d. alc.                          |  |                                    | 15 |
| IV. G.                            | 0.33                                 | s.                                     | s. alc.                          |  |                                    | 16 |
|                                   | 0.26                                 | s.s.                                   | i. alc., s.s. ac.                |  |                                    | 17 |
| IV.                               | i.                                   | i.                                     | s.s. $\text{H}_2\text{SO}_4$     | 1500                                   |                                    | 18 |
| IV.                               | d.                                   |  | i. alc.                          | d.                                     |                                    | 19 |
| I., prism.                        | i.                                   |  | s. ac.                           |  |                                    | 20 |
| VI.                               | d.                                   |  | s. ac.                           |  |                                    | 21 |
|                                   |                                      |  |                                  |  |                                    | 22 |
| IV. P.                            | 50                                   |  | i. alk.                          | 268                                    | 1090—1450                          | 23 |
| IIIa.                             | i.                                   |  | s. $\text{HNO}_3$                | aq 100                                 | becomes<br>$\text{Bi}_2\text{O}_3$ | 24 |
| W. pdr.                           | i.                                   | i.                                     |                                  |  |                                    |    |
| W.                                | i.                                   |  | s. ac.                           | aq 100                                 |                                    | 25 |
|                                   | i.                                   |  | s.s. $\text{HNO}_3$              |  |                                    | 26 |
| VI.                               | d.                                   |  | s. $\text{HNO}_3$                | 74                                     | 5 aq 80                            | 27 |
| VI. W.                            | i.                                   |  | s. min. ac.                      | d.                                     |                                    | 28 |
| W., cryst.                        | i.                                   |  | s. HCl                           | R.H.                                   |                                    | 29 |
| R. Br.                            | i.                                   | i.                                     | s. HCl                           | d. 225                                 |                                    | 30 |
| Micro cryst.                      | i.                                   | i.                                     |                                  | d.                                     |                                    | 31 |
| W                                 | d.                                   |  |                                  | d.                                     |                                    | 32 |

| Name.                | Formula.   | Density.        |                    |
|----------------------|--|-----------------|--------------------|
|                      |  | Formula Weight. | Water=1<br>D:Air=1 |
| 1 Bismuth tribromide | $\text{BiBr}_3$  | 448.8           | 5.604              |
| 2 — trichloride      | $\text{BiCl}_3$  | 315.4           | 4.6/11°            |
| 3 — tri-iodide       | $\text{BiI}_3$   | 589.8           | 5.65/20°           |
| 4 — trioxide         | $\text{Bi}_2\text{O}_3$                                  | 466.0           | 8.868              |
| 5 — trisulphide      | $\text{Bi}_2\text{S}_3$                                  | 514.2           | 6.5 ppd.           |
| 6 Borax              | $\text{Na}_2\text{B}_4\text{O}_7 + 10\text{H}_2\text{O}$ | 386.2           | 1.69               |
| 7 Boric acid         | $\text{H}_3\text{BO}_3$                                  | 63.0            | 1.4347/15°         |
| 8 Borofluoric acid   | $\text{HBF}_4$   | 89.0            |                    |
| 9 Boron              | B  | 10.9            | 2.68; am. 2.45     |
| 10 — nitride         | BN   | 24.9            |                    |
| 11 — tribromide      | $\text{BBr}_3$   | 250.7           | 2.69               |
| 12 — trichloride     | $\text{BCl}_3$   | 117.3           | 1.95/0°            |
| 13 — trifluoride     | $\text{BF}_3$  | 67.9            |                    |
| 14 — tri-iodide      | $\text{BI}_3$  | 391.7           | 3.3/50°            |
| 15 — trioxide        | $\text{B}_2\text{O}_3$                                   | 69.9            | 1.83/4°            |
| 16 — trisulphide     | $\text{B}_2\text{S}_3$                                   | 118.0           | 1.55               |
| 17 Bromic acid       | $\text{HBrO}_3$  | 128.93          |                    |
| 18 Bromine           | Br   | 79.92           | 3.1872             |
| 19 — monochloride    | $\text{BrCl} + 10\text{H}_2\text{O}$                     | 295.54          |                    |
| 20 — mono-iodide     | $\text{BrI}$   | 206.84          | 4.4157/0°          |
| 21 — sulphide        | $\text{Br}_2\text{S}_2$                                  | 223.96          | 2.629              |
| 22 Cadmium           | Cd   | 112.40          | 8.64               |
| 23 — bromide         | $\text{CdBr}_2$  | 272.24          | 4.794/20°          |
| 24 — carbonate       | $\text{CdCO}_3$  | 172.40          | 4.49               |
| 25 — chlorate        | $\text{Cd}(\text{ClO}_3)_2 + 2\text{H}_2\text{O}$        | 315.35          | 2.284/18°          |
| 26 — chloride        | $\text{CdCl}_2 + 2\text{H}_2\text{O}$                    | 219.35          | 3.6/15°            |
| 27 — — anhydr.       | $\text{CdCl}_2$  | 183.32          | 3.655/17°          |
| 28 — fluoride        | $\text{CdF}_2$   | 150.40          | 5.99/22°           |
| 29 — hydroxide       | $\text{Cd}(\text{OH})_2$                                 | 146.42          | 4.79               |
| 30 — iodate          | $\text{Cd}(\text{IO}_3)_2 + \text{H}_2\text{O}$          | 480.25          |                    |
| 31 — iodide          | $\text{CdI}_2$   | 366.24          | 4.576              |
| 32 — nitrate         | $\text{Cd}(\text{NO}_3)_2 + 4\text{H}_2\text{O}$         | 312.48          | 2.45               |

| Crystalline form and colour | Solubility*in                 |                                 | Alcohol, acids or alkalies                           | M.P. °C.      | B.P. °C. |    |
|-----------------------------|-------------------------------|---------------------------------|--|---------------|----------|----|
|                             | 100 parts water at 15°C(60°F) | 100 parts water at 100°C(212°F) |  |               |          |    |
| Y., prism.                  | deliq., d.                    |                                 | s. HCl   | 210—215       | 453      | 1  |
| W., cryst.                  | deliq., d.                    |                                 | s. HCl   | 227           | 429      | 2  |
| Bl., cryst.                 | s.                            | d.                              | s. HI  | subl.         | <439     | 3  |
| Y.W.                        | s.                            |                                 | s. alc.  | ppd. 820      |          | 4  |
| IV.                         | i.                            |                                 | s. HNO <sub>3</sub>                                  | d.            |          | 5  |
| V., +5aq.I.                 | 6.2                           | 201.4                           | i. alc.  | R.H.          |          | 6  |
| VI.                         | 4                             | 34                              | 1:6 alc.   | 185, aq. 100, |          | 7  |
|                             | s.                            | s.                              |  | liq.          | d. 130   | 8  |
| V., Y.;                     | i.                            | i.                              | i. alc.  | 2200—2500     |          | 9  |
| Am., W.                     | i.                            | i.                              | d. HF  |               |          | 10 |
|                             | d.                            |                                 |  | liq.          | 90.5     | 11 |
| O.                          | d                             |                                 |  | liq.          | 18.2     | 12 |
|                             | 1000 vol. in 1                | d.                              | d. in alc.   | -127          | -101     | 13 |
| O. cryst.                   | d.                            |                                 | s. CS <sub>2</sub> and C <sub>6</sub> H <sub>6</sub> | 43            | 210      | 14 |
| O.                          | d.                            |                                 | s. alc.  | <1500         |          | 15 |
| W.                          | d.                            |                                 | d., s. PCl <sub>3</sub>                              | 310           |          | 16 |
| O.                          | s.                            | s.                              |  |               | d. 100   | 17 |
| Br.                         | 3.5                           |                                 | s. alc.  | -7.3          | 63       | 18 |
| Y.                          | v.s.                          |                                 |  | an. 7         |          | 19 |
|                             | d.                            |                                 | s. CS <sub>2</sub> and CHCl <sub>3</sub>             | 36            |          | 20 |
| R.                          | d.                            |                                 |  | liq.          | 190—200  | 21 |
| III.                        | i.                            | i.                              | s. HNO <sub>3</sub> , HCl                            | 320.9         | 778      | 22 |
| W.                          | deliq.                        | 49                              | s. HCl, s. alc.                                      | 580           | 863      | 23 |
| W.                          | i.                            | i.                              | s. ac.   |               |          | 24 |
| Prism.                      | deliq.                        | v.s.                            | s. alc.  | d. 80         |          | 25 |
| Cryst.                      | 140                           | 150                             | s. alc.  | 590           | 900      | 26 |
|                             | 140.8                         | 150                             | s. alc.  | 560           | 964      | 27 |
|                             | s.s.                          | s.s.                            | s. HF., i. alc.                                      | 520           |          | 28 |
| W.                          | i.                            | i.                              | s. ac.   | aq 300        |          | 29 |
| V., small cryst.            | s.s.                          | s.s.                            | s. HNO <sub>3</sub>                                  | d.            |          | 30 |
| Cryst.                      | 89                            | 132                             | s. alc., ether                                       | 350           | 716      | 31 |
|                             | 127                           | v.s.                            | s. alc.  | 59.5          | 132      | 32 |

| Name                    | Formula.  | Density.         |                    |
|-------------------------|---|------------------|--------------------|
|                         |   | Formula Weight.  | Water=1<br>D:Air=1 |
| 1 Cadmium oxide         | CdO   | 128.40           | 6.95               |
| 2 —sulphate             | (a) $3 \text{ CdSO}_4 + 8 \text{ H}_2\text{O}$<br>(b) $\text{CdSO}_4 + 4 \text{ H}_2\text{O}$ | 769.51<br>284.52 | 3.05               |
| 3 — sulphide            | CdS   | 144.50           | 4.58 ppd.          |
| 4 Cesium carbonate      | $\text{Cs}_2\text{CO}_3$  | 325.62           |                    |
| 5 — chloride            | CsCl  | 168.27           | 3.972/20°          |
| 6 — hydroxide           | CsOH  | 149.82           | 4.018/4°           |
| 7 — nitrate             | $\text{CsNO}_3$   | 194.82           | 3.687/28°          |
| 8 — platinichloride     | $\text{Cs}_2\text{PtCl}_6$  | 673.6            |                    |
| 9 — silicofluoride      | $\text{Cs}_2\text{SiF}_6$   | 407.7            | 3.375/17°          |
| 10 — sulphate           | $\text{Cs}_2\text{SO}_4$  | 361.68           | 4.250/16°          |
| 11 Calcium              | Ca  | 40.07            | 1.554/18°          |
| 12 — arsenate           | $\text{Ca}_3(\text{AsO}_4)_2$   | 398.13           |                    |
| 13 — bromide            | $\text{CaBr}_2 (+6 \text{ H}_2\text{O})$  | 199.91           | 3.32/20°           |
| 14 — carbide            | $\text{CaC}_2$  | 64.08            | 2.22/18°           |
| 15 — carbonate          | $\text{CaCO}_3$   | 100.08           | 2.72—2.9           |
| 16 — chlorate           | $\text{Ca}(\text{ClO}_3)_2 (+2 \text{ H}_2\text{O})$  | 206.99           |                    |
| 17 — chloride           | $\text{CaCl}_2 + 6 \text{ H}_2\text{O}$   | 219.09           | 1.6775/17°         |
| 18 — — anhydr.          | $\text{CaCl}_2$   | 110.99           | 2.26/20°           |
| 19 — chromate           | $\text{CaCrO}_4 + 2 \text{ H}_2\text{O}$  | 192.1            |                    |
| 20 — cyanide            | $\text{Ca}(\text{CN})_2$  | 92.10            |                    |
| 21 — cyanamide          | $\text{CaCN}_2$   | 80.09            |                    |
| 22 — ferrocyanide       | $\text{Ca}_2\text{Fe}(\text{CN})_6 + 12 \text{ H}_2\text{O}$                                  | 508.31           |                    |
| 23 — fluoride           | $\text{CaF}_2$  | 78.07            | 3.18               |
| 24 — hydrogen phosphate | $\text{CaHPO}_4 + 2 \text{ H}_2\text{O}$  | 172.15           | 2.3                |
| 25 — hydrosulphide      | $\text{Ca}(\text{HS})_2 (+6 \text{ H}_2\text{O})$   | 106.21           |                    |
| 26 — hydroxide          | $\text{Ca}(\text{OH})_2$  | 74.09            | 2.078 am.          |
| 27 — hypochlorite       | $\text{Ca}(\text{OCl})_2 + 4 \text{ H}_2\text{O}$   | 215.05           |                    |
| 28 — hypophosphite      | $\text{Ca}(\text{H}_2\text{PO}_2)_2$  | 170.18           |                    |
| 29 — iodate             | $\text{Ca}(\text{IO}_3)_2 (+6 \text{ H}_2\text{O})$   | 389.91           |                    |
| 30 — iodide             | $\text{CaI}_2 (+6 \text{ H}_2\text{O})$   | 293.91           | 4.9/20° an.        |

| Crystalline<br>form and<br>colour | Solubility*in                        |  | Alcohol,<br>acids<br>or alkalies | M.P.<br>°C. | B.P.<br>°C.                      |    |
|-----------------------------------|--------------------------------------|--|----------------------------------|-------------|----------------------------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) |                                  |             |                                  |    |
| I., Br., R.                       | i.                                   | i.                                     |                                  |             |                                  | 1  |
| V.                                | 59                                   | v.s.                                   |                                  | an.         |                                  | 2  |
|                                   | 95                                   | v.s.                                   | i. alc.                          | 1000        |                                  |    |
| III. Y.                           | i.                                   | i.                                     | s. conc. ac.                     | W.H.        |                                  | 3  |
|                                   | deliq.                               | v.s.                                   | s. alc.<br>11.1/19°              | <R.H.       | d. 610                           | 4  |
| I. C.                             | 174                                  | v.s.                                   | s. alc.                          | 631         | subl.                            | 5  |
|                                   | deliq.                               | v.s.                                   | s. alc.                          |             |                                  | 6  |
| II.                               | 10.58/3.2°                           |  | s.s. alc.                        | 414         | d.                               | 7  |
| I. Y.                             |                                      | v.s.s.                                 |                                  |             |                                  | 8  |
| I. -                              | 6                                    | s.                                     | i. alc.                          |             |                                  | 9  |
| C.                                | 158.7/-2°                            | v.s.                                   | i. alc.                          |             |                                  | 10 |
| IIIa. Y.                          | d.                                   |  | d.                               | 805         |                                  | 11 |
|                                   | i.                                   | i.                                     |                                  |             |                                  | 12 |
| W. needles                        | 140                                  | 310                                    | v.s. alc.                        | 760         | 800                              | 13 |
| Gr. Y.                            | gives                                |  | not d. conc.                     |             |                                  | 14 |
| cryst.                            | $C_2H_2$                             |  | $H_2SO_4$                        |             |                                  |    |
| IIIa, IV.                         | 0.0018                               | 0.088                                  | $CO_2$ with acids                | d. 825      |                                  | 15 |
| V.                                | deliq.                               | v.s.                                   | v.s. alc., s. acet.              | d.          |                                  | 16 |
| III.                              | 400                                  | 650                                    | alc. 13                          | 29          | 4 aq 30<br>in vacuo,<br>6 aq 200 | 17 |
| Am. W.                            | 66                                   | 155                                    |                                  | 780         |                                  | 18 |
| Y. cryst.                         | 0.4                                  | s.                                     |                                  | 2 aq R.H.   |                                  | 19 |
| I.                                | s.                                   | s.                                     |                                  |             |                                  | 20 |
|                                   |                                      | s. d.                                  |                                  | d.          |                                  | 21 |
| Y. prism.                         | (+12 aq)<br><150                     | 150 (90°)                              |                                  | d.          |                                  | 22 |
| I.                                | 0.05                                 | v.s.s.                                 |                                  | 1330        |                                  | 23 |
| V. W.                             | s.s.                                 | d.                                     | s. amm. cit ate                  | an. 100     |                                  | 24 |
| Cryst.                            | v.s.                                 |  | s. alc.                          |             | d.                               | 25 |
| W. needles                        | 0.137                                | 0.075                                  | i. alc.                          |             |                                  | 26 |
|                                   | deliq. & s.                          |  |                                  | d.          |                                  | 27 |
| V.                                | 17                                   | slightly<br>>17                        | i. alc.                          | d. R.H.     |                                  | 28 |
| IV.                               | 0.4                                  | 1.33                                   | s. $HNO_3$                       | d.          |                                  | 29 |
| W. plates.                        | 201                                  | 435/92°                                | s. acetone                       | 740         |                                  | 30 |

| Name.                                | Formula.   | Density.        |                          |
|--------------------------------------|--|-----------------|--------------------------|
|                                      |  | Formula Weight. | Water=1<br>D:Air=1       |
| 1 Calcium nitrate                    | $\text{Ca}(\text{NO}_3)_2 + 4 \text{H}_2\text{O}$                            | 236.15          | 1.878/18°                |
| 2 — nitride                          | $\text{Ca}_3\text{N}_2$  | 148.23          | 2.63/17°                 |
| 3 — nitrite                          | $\text{Ca}(\text{NO}_2)_2 (+\text{H}_2\text{O})$                             | 132.09          |                          |
| 4 — oxide                            | $\text{CaO}$   | 56.07           | 3.08                     |
| 5 — peroxide                         | $\text{CaO}_2 + 8 \text{H}_2\text{O}$  | 216.20          |                          |
| 6 — phosphate, ortho-                | $\text{Ca}_3(\text{PO}_4)_2$   | 310.29          | 3.18                     |
| 7 — — meta-                          | $\text{Ca}(\text{PO}_3)_2$   | 198.15          |                          |
| 8 — — pyro-                          | $\text{Ca}_2\text{P}_2\text{O}_7 (+4 \text{H}_2\text{O})$                    | 254.22          |                          |
| 9 — phosphide                        | $\text{Ca}_3\text{P}_2$  | 182.29          | 2.51/15°                 |
| 10 — plumbate                        | $\text{Ca}_2\text{PbO}_4$  | 351.94          |                          |
| 11 — plumbite                        | $\text{CaPbO}_3$   | 279.27          |                          |
| 12 — potassium sulphate              | $\text{CaSO}_4 \cdot \frac{1}{2} \text{K}_2\text{SO}_4 + \text{H}_2\text{O}$ | 328.41          | 2.6/17°                  |
| 13 — sodium sulphate                 | $\text{CaSO}_4 \cdot 2 \text{Na}_2\text{SO}_4 + 2 \text{H}_2\text{O}$        | 456.28          |                          |
| 14 — sulphate (gypsum)               | $\text{CaSO}_4 + 2 \text{H}_2\text{O}$                                       | 172.16          | 2.306/15°                |
| 15 — sulphide                        | $\text{CaS}$   | 72.13           | 2.8                      |
| 16 — sulphite                        | $\text{CaSO}_3 + 2 \text{H}_2\text{O}$                                       | 156.17          |                          |
| 17 — tetrahydrogen<br>orthophosphate | $\text{CaH}_4(\text{PO}_4)_2 + \text{H}_2\text{O}$                           | 252.20          | 2/4°                     |
| 18 — thiosulphate                    | $\text{CaS}_2\text{O}_3 + 6 \text{H}_2\text{O}$                              | 260.29          | 1.87                     |
| 19 Carbon (diamond)                  | $\text{C}$   | 12.00           | 3.48—3.53                |
| 20 — (graphite)                      | $\text{C}$   | 12.00           | 2.14—2.27                |
| 21 — dioxide                         | $\text{CO}_2$  | 44.00           | liq. 0.83;<br>solid. 1.2 |
| 22 — disulphide                      | $\text{CS}_2$  | 76.12           | D. 2.68; 1.292           |
| 23 — monoxide                        | $\text{CO}$  | 28.00           | liq. 0.7929              |
| 24 — oxysulphide                     | $\text{COS}$   | 60.06           |                          |
| 25 — tetrachloride                   | $\text{CCl}_4$   | 153.84          | 1.582/21°                |
| 26 Carbonyl chloride<br>(phosgene)   | $\text{COCl}_2$  | 98.92           | 1.432/0°<br>1.392/18.6°  |
| 27 Ceric sulphate                    | $\text{Ce}(\text{SO}_4)_2$   | 332.37          |                          |
| 28 Cerium                            | $\text{Ce}$  | 140.25          | 6.6—7.0                  |
| 29 — dioxide                         | $\text{CeO}_2$   | 172.25          | 6.74                     |
| 30 — sesquioxide                     | $\text{Ce}_2\text{O}_3$  | 328.50          | 6.9—7.0                  |



| Crystalline form and colour | Solubility* in                 |                                  | Alcohol, acids or alkalies                   | M.P. °C.          | B.P. °C.      |    |
|-----------------------------|--------------------------------|----------------------------------|--|-------------------|---------------|----|
|                             | 100 parts water at 15°C (60°F) | 100 parts water at 100°C (212°F) |  |                   |               |    |
| V.                          | 54.8                           | v.s.                             | s. alc.                                      | 44, an. 561       | d. 132        | 1  |
| Br.                         | d.                             |                                  |  | 900               |               | 2  |
| III., prism                 | v.s.                           | v.s.                             | s.s. alc.                                    | aq 100            |               | 3  |
| O., I.                      | d.                             |                                  | s. alc.                                      |                   |               | 4  |
| II.                         | s.s.                           |                                  | i. alc.                                      | 8 aq 130          | d.            | 5  |
| W.                          | i.                             | i.                               | s. ac.                                       | fusible           |               | 6  |
| W.                          | i.                             | i.                               | i ac.  |                   |               | 7  |
| W.                          | i.                             |                                  | s. ac.                                       |                   |               | 8  |
| Cryst.                      | yields pure $\text{PH}_3$      |                                  |  | burns in O at 300 |               | 9  |
| Br., cryst.                 | i.                             | d.                               | d. ac.                                       | d.                |               | 10 |
| Cryst.                      |                                | s.s.                             |  | d.                |               | 11 |
| V.                          | s.s.                           | d.                               | i. alc.                                      |                   |               | 12 |
| V.                          |                                | d.                               |  | 2 aq 80           |               | 13 |
| V. W.                       | 0.24 (0°)                      | 0.22                             | i. alc.                                      | 2 aq 130          |               | 14 |
| I. W.                       | d.                             |                                  |  |                   | d.            | 15 |
| W. needles                  | 0.125                          |                                  | s. $\text{SO}_2$ soln                        | 2 aq 100          |               | 16 |
| IV.                         | 0.128                          | 0.079                            | s. acids                                     | aq 100            | d. 200        | 17 |
| VI.                         | 100 (3°)                       | d.                               |  | d.                |               | 18 |
| I., C.                      | i.                             | i.                               | i  |                   |               | 19 |
| III., Gr.                   | i.                             | i.                               | i  |                   |               | 20 |
|                             | 1.797 in 1 vol. (0°)           |                                  | alc. 1 : 3.2 vol. (15°)                      | -65               | -78.2         | 21 |
|                             | 2 : 1000/0° 30 vol.            | 1.4 : 10000/50°                  | m. alc.                                      | -116              | 46            | 22 |
|                             |                                |                                  | sol. in am. or acid $\text{Cu}_2\text{Cl}_2$ | -207/100 mm.      | -190          | 23 |
| gas.                        | 1 : 1 vol.                     |                                  |  | d.                | 0° at 12 atm. | 24 |
|                             | i.                             |                                  |  | -23.8             | 76.7          | 25 |
|                             | d.                             |                                  | d. alc.                                      | gas               | 8             | 26 |
| Y. cryst. pdr.              | forms basic salt               |                                  |  |                   |               | 27 |
| Gr. met.                    | d.                             |                                  | s. $\text{HCl}$ , $\text{HNO}_3$             | 623               |               | 28 |
| W pdr.                      | i.                             | i.                               | s. $\text{H}_2\text{SO}_4$                   |                   |               | 29 |
| G pdr.                      |                                |                                  | s. $\text{H}_2\text{SO}_4$ , i. $\text{HCl}$ |                   |               | 30 |

| Name.                  | Formula.   | Density.        |                                   |
|------------------------|--|-----------------|-----------------------------------|
|                        |  | Formula Weight. | Water=1<br>D:Air=1                |
| 1 Cerous carbonate     | $\text{Ce}_2(\text{CO}_3)_3 + 5 \text{H}_2\text{O}$            | 550.59          |                                   |
| 2 — chloride           | $\text{CeCl}_3$  | 246.63          | 3.88/15.5°                        |
| 3 — phosphate          | $\text{CePO}_4$  | 235.29          | 5.92/14°                          |
| 4 — sulphate           | $\text{Ce}_2(\text{SO}_4)_3$                                   | 568.68          | 3.91                              |
| 5 Chlorauroic acid     | $\text{HAuCl}_4 + 4 \text{H}_2\text{O}$                        | 412.1           |                                   |
| 6 Chloric acid         | $\text{HClO}_4 (+7 \text{H}_2\text{O})$                        | 84.47           | 1.282                             |
| 7 Chlorine             | $\text{Cl}$  | 35.46           | liq. :1.33/14°;<br>D :2.4502/200° |
| 8 — dioxide            | $\text{ClO}_2$   | 67.46           | 1.5; D :2.39                      |
| 9 — heptoxide          | $\text{Cl}_2\text{O}_7$  | 182.92          |                                   |
| 10 — hydrate           | $\text{Cl}_2 + 8 \text{H}_2\text{O}$                           | 215.05          | 1.2                               |
| 11 — monoxide          | $\text{Cl}_2\text{O}$  | 86.92           | liq. 3.87                         |
| 12 Chlorplatinic acid  | $\text{H}_2\text{PtCl}_6$                                      | 410.0           | 2.431                             |
| 13 Chlorsulphonic acid | $\text{ClSO}_3\text{OH}$                                       | 116.53          | 1.72/18°                          |
| 14 Chromic acid        | $\text{H}_2\text{CrO}_4$                                       | 118.0           |                                   |
| 15 — bromide           | $\text{Cr}_2\text{Br}_6$                                       | 583.5           |                                   |
| 16 — chloride          | $\text{Cr}_2\text{Cl}_6$                                       | 317.8           | D :5.51/1277°;<br>2.76/15°        |
| 17 — fluoride          | $\text{Cr}_2\text{F}_6$  | 218.0           | 3.78                              |
| 18 — hydroxide         | $\text{Cr}_2(\text{OH})_6 + 4 \text{H}_2\text{O}$              | 278.1           |                                   |
| 19 — nitrate           | $\text{Cr}(\text{NO}_3)_3 + 9 \text{H}_2\text{O}$              | 400.17          |                                   |
| 20 — sulphate          | $\text{Cr}_2(\text{SO}_4)_3 + 18 \text{H}_2\text{O}$           | 716.5           | 1.867/15°                         |
| 21 — sulphide          | $\text{Cr}_2\text{S}_3$  | 200.2           | 3.77                              |
| 22 Chromium            | $\text{Cr}$  | 52.0            | 6.92/20°                          |
| 23 — sesquioxide       | $\text{Cr}_2\text{O}_3$  | 152.0           | 5.21 cryst.                       |
| 24 — trioxide          | $\text{CrO}_3$   | 100.0           | 2.74 cryst.                       |
| 25 Chromous chloride   | $\text{CrCl}_2$  | 122.9           | 2.75/14°                          |
| 26 Chromyl chloride    | $\text{CrO}_2\text{Cl}_2$                                      | 154.9           | 1.96                              |
| 27 Cobalt              | $\text{Co}$  | 58.97           | 8.951                             |
| 28 Cobaltic chloride   | $\text{Co}_2\text{Cl}_6$                                       | 330.70          | 2.94                              |
| 29 —, luteo            | $\text{Co}_2(\text{NH}_3)_4\text{Cl}_4$                        | 535.08          | 1.7/20°                           |
| 30 —, praseo           | $\text{Co}_2(\text{NH}_3)_8\text{Cl}_4 + 2 \text{H}_2\text{O}$ | 503.00          |                                   |
| 31 —, purpureo         | $\text{Co}_2(\text{NH}_3)_6\text{Cl}_4$                        | 501.00          | 1.802/23°                         |
| 32 —, roseo            | $\text{Co}_2(\text{NH}_3)_4\text{Cl}_6 + 2 \text{H}_2\text{O}$ | 537.0           |                                   |
| 33 —, xantho           | $\text{Co}_2(\text{NH}_3)_4(\text{NO}_2)_2\text{Cl}_4$         | 522.10          |                                   |
| 34 Cobalticyanic acid  | $(\text{H}_3\text{Co}(\text{CN})_6)_2 + \text{H}_2\text{O}$    | 454.18          |                                   |

| Crystalline<br>form and<br>colour | Solubility*in                        |  |                                     | M.P.<br>°C.          | B.P.<br>°C. |    |
|-----------------------------------|--------------------------------------|--|-------------------------------------|----------------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) | Alcohol,<br>acids<br>or alkalies    |                      |             |    |
| Plates                            | i.                                   |  | s. $(\text{NH}_4)_2\text{CO}_3$     |                      |             | 1  |
| C.                                | s.                                   |  | s. alc.                             | fusible              | d.          | 2  |
| V. R.                             | i.                                   | i.                                     | i. ac.                              |                      |             | 3  |
| G. pdr.                           | 40/0°                                | 0.775                                  |                                     |                      |             | 4  |
| Y. needles                        | s.                                   | v.s.                                   | s. alc.                             | d.                   |             | 5  |
|                                   | s.                                   |  |                                     | d.                   | d.          | 6  |
| G.                                | 1:2.6 vol.                           | 1:1.4, 40°                             |                                     | -102                 | -33.5       | 7  |
| R.                                | 20 vol. :1                           |  | alk. d.                             | -76                  | 10/731 mm.  | 8  |
| O.                                | d.                                   |  | s. $\text{C}_6\text{H}_6$           |                      | 82          | 9  |
| I. Y.                             | s.                                   |  | s. $\text{HCl}$                     | d. 9.6               |             | 10 |
| Y. R.                             | s.                                   |  |                                     | expl.                | 19          | 11 |
| R. cryst.                         | deliq.                               | v.s.                                   |                                     |                      |             | 12 |
| C.                                | d.                                   |  | d.                                  | liq.                 | 158         | 13 |
| R. cryst.                         | s.                                   | v.s.                                   |                                     | gives $\text{CrO}_3$ |             | 14 |
| dark.                             | i.                                   | s.                                     | alk. d.                             |                      | subl.       | 15 |
| P.                                | i.                                   | i.                                     | i. alc.                             |                      | 1300        | 16 |
| G.                                | i.                                   |  |                                     | >1000                | subl.       | 17 |
| B.                                | i.                                   | i.                                     | s. ac., alk.                        | 3 aq in vac          |             | 18 |
|                                   |                                      |  | s. $\text{NaHSO}_3$                 | 4 aq 100             |             |    |
| Viol. prism                       | s.                                   | v.s.                                   | s. alk.                             | 36.5                 |             | 19 |
| I., Viol.                         | 120                                  | s. green 90°                           | s. alc.                             | 4 aq 100             | an. 400     | 20 |
| R.                                |                                      |  | s. $\text{HNO}_3$                   |                      |             | 21 |
| IIIa, G.                          | i.                                   | i.                                     | s. $\text{HCl}$ , i. $\text{HNO}_3$ | 1505                 |             | 22 |
| III., G.                          | i.                                   | i.                                     | i. alc.                             | W. H.                |             | 23 |
| IV., R.                           | v.s.                                 | v.s.                                   | alc. d.                             | 190                  | d.          | 24 |
| W.                                | s.                                   | s.                                     |                                     | fusible              |             | 25 |
| R.                                | d.                                   |  | alc. d.                             | liq.                 | 116         | 26 |
| Gr. met.                          | i.                                   | i.                                     | s. ac.                              | 1490                 |             | 27 |
|                                   | s.                                   | s.                                     | s. alc.                             | d.                   |             | 28 |
| V. R. Y.                          | 1:16.8                               | v.s.                                   | s. conc. $\text{HCl}$               | d.                   |             | 29 |
| G. cryst.                         | v.s.                                 |  |                                     | d.                   |             | 30 |
|                                   | 1:255                                | s.                                     | s. conc. $\text{H}_2\text{SO}_4$    | d.                   |             | 31 |
| R. cryst.                         | 1:4.8                                | d.                                     | i. alc.                             | d. 100               |             | 32 |
| Y. cryst.                         | s.s.                                 | s. d.                                  |                                     |                      |             | 33 |
| O. needles                        | deliq.                               |  | s. alc.                             | d. <100              |             | 34 |

| Name.                                | Formula.  | Density. |                             |
|--------------------------------------|---|----------|-----------------------------|
|                                      |   | Formula  | Water=1<br>Weight. D:Air=1. |
| 1 Cobaltic hydroxide                 | $\text{Co}_2(\text{OH})_4$                          | 219.99   |                             |
| 2 — oxide                            | $\text{Co}_2\text{O}_3$                             | 165.94   | 5.1                         |
| 3 Cobalto-cobaltic oxide             | $\text{Co}_3\text{O}_4$                             | 240.91   | 5.8—6.3                     |
| 4 Cobalt arsenate                    | $\text{Co}_3(\text{AsO}_4)_2 + 8\text{H}_2\text{O}$ | 598.96   | 2.948                       |
| 5 — bromide                          | $\text{CoBr}_2 + 6\text{H}_2\text{O}$               | 326.91   |                             |
| 6 — carbonate                        | $\text{CoCO}_3$                                     | 118.97   |                             |
| 7 — chlorate                         | $\text{Co}(\text{ClO}_3)_2 + 6\text{H}_2\text{O}$   | 333.99   |                             |
| 8 — chloride                         | $\text{CoCl}_2 + 6\text{H}_2\text{O}$               | 237.99   | 1.84                        |
| 9 — —, anhydr.                       | $\text{CoCl}_2$                                     | 129.89   | 2.94                        |
| 10 — cyanide                         | $\text{Co}(\text{CN})_2 + 3\text{H}_2\text{O}$      | 165.05   |                             |
| 11 — hydroxide                       | $\text{Co}(\text{OH})_2$                            | 92.99    | 3.507/15°                   |
| 12 — nitrate                         | $\text{Co}(\text{NO}_3)_2 + 6\text{H}_2\text{O}$    | 291.09   | 1.83                        |
| 13 — phosphate                       | $\text{Co}_3(\text{PO}_4)_2 + 8\text{H}_2\text{O}$  | 511.12   |                             |
| 14 — oxide                           | $\text{CoO}$  | 74.97    | 5.68                        |
| 15 — silicate                        | $\text{Co}_2\text{SiO}_4$                           | 210.0    | 4.63                        |
| 16 — sulphate                        | $\text{CoSO}_4 + 7\text{H}_2\text{O}$               | 281.14   | 1.98/15°                    |
| 17 — sulphide                        | $\text{CoS}$  | 91.03    |                             |
| 18 — tetracarbonyl                   | $\text{Co}_2(\text{CO})_8$                          | 341.98   |                             |
| 19 — tricarbonyl                     | $\text{Co}(\text{CO})_3$                            | 142.99   |                             |
| 20 Columbium                         | $\text{Cb}$   | 93.1     | 8.4                         |
| 21 — dioxide                         | $\text{Cb}_2\text{O}_3$                             | 218.2    | 6.3                         |
| 22 — hydride                         | $\text{CbH}_3$                                      | 94.1     | 6.6                         |
| 23 — oxychloride                     | $\text{CbOCl}_3$                                    | 215.5    | D:7.88/400°                 |
| 24 — pentachloride                   | $\text{CbCl}_5$                                     | 270.4    | D:9.6/360°;<br>4.4—4.5      |
| 25 — pentoxide                       | $\text{Cb}_2\text{O}_5$                             | 266.2    | 4.53—4.57                   |
| 26 Copper                            | $\text{Cu}$   | 63.57    | 8.94/20°                    |
| 27 — carbonate, basic<br>(malachite) | $\text{CuCO}_3 + \text{Cu}(\text{OH})_2$            | 221.16   | 3.65—4.05                   |
| 28 — — — (azurite)                   | $2\text{CuCO}_3 + \text{Cu}(\text{OH})_2$           | 344.73   | 3.88                        |
| 29 — dioxide                         | $\text{CuO}_2 + \text{H}_2\text{O}$                 | 113.59   |                             |
| 30 Cuprammonium<br>sulphate          | $\text{CuSO}_4 + 4\text{NH}_3 + \text{H}_2\text{O}$ | 245.80   |                             |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       | Alcohol,<br>acids<br>or alkalis | M.P.<br>°C.           | B.P.<br>°C. |    |
|-----------------------------------|-------------------------------------|---------------------------------------|---------------------------------|-----------------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) |                                 |                       |             |    |
| Bl.                               | i.                                  | i.                                    | i. alc., d. HCl                 |                       | 6 aq 100    | 1  |
| Br.                               | i.                                  | i.                                    | i. alc., s. ac.                 | d. R.H.               |             | 2  |
| I., Bl.                           | i.                                  | i.                                    | s. conc. $H_2SO_4$              |                       |             | 3  |
| V., Viol.                         | i.                                  | i.                                    | s. HCl                          | d.                    |             | 4  |
| R. prism.                         | s.                                  | v.s.                                  | s. alc., ether                  | 4 aq 100,<br>2 aq 130 | an. 130     | 5  |
| IIIa, R.                          | i.                                  | i.                                    | alc.                            | d.                    |             | 6  |
| I.                                | deliq.                              |                                       | s. alc.                         | 50                    | d. 100      | 7  |
| V., R.                            |                                     | s.                                    | s. alc.                         | 86.75                 | 6 aq 110    | 8  |
| B.                                | 50                                  | 108                                   | s. alc.                         | subl. in Cl           |             | 9  |
| Am. R.                            | i.                                  |                                       | s. KCN                          | 3 aq 250              |             | 10 |
| P. cryst.                         | i.                                  | i.                                    | s. $NH_4OH$                     |                       |             | 11 |
| P. cryst.                         | deliq.                              | v.s.                                  | alc. 200                        | d. R.H.               |             | 12 |
|                                   | i.                                  | i.                                    | i. alc.                         | d.                    |             | 13 |
| Br.                               | i.                                  | i.                                    | i. alc.                         | d. 100                |             | 14 |
| Viol.                             | i.                                  |                                       | d. HCl                          |                       |             | 15 |
| IV., R.                           | 32.0                                | 82.6                                  | i. alc.                         |                       |             | 16 |
| Gr., Pr.                          | i.                                  | i.                                    | s. acids                        |                       |             | 17 |
| Or. cryst.                        | i.                                  |                                       | s. alc. $CS_2$                  | 51                    | d. 60       | 18 |
| Bl. cryst.                        | s.s.                                |                                       | d. with Br                      |                       |             | 19 |
| Gr.                               |                                     |                                       | s. conc. $H_2SO_4$              | 1950                  |             | 20 |
| I. Bl.                            | i.                                  | i.                                    | s. HCl                          |                       |             | 21 |
| Gr., pdr.                         |                                     |                                       | s. HF, conc.<br>$H_2SO_4$       | ignites               |             | 22 |
| W.                                | d.                                  |                                       | s. $KOH$ , alc.                 |                       | subl. 400   | 23 |
| Y. needles                        | d.                                  |                                       | s. HCl, $CCl_4$                 | 194                   | 240.5       | 24 |
| Am. W.,<br>cryst. G.              | i.                                  | i.                                    | s. $H_2SO_4$                    | infusible             |             | 25 |
| I., R.                            | i.                                  | i.                                    | s. ac.                          | 1083.0                |             | 26 |
| V. G.                             | i.                                  | i.                                    | s. $NH_4OH$                     | d.                    |             | 27 |
| V. B.                             | i.                                  | i.                                    |                                 | d.                    |             | 28 |
| Y.Br.                             | i.                                  |                                       | i. alc.                         | aq d. 6               | an. d. 180  | 29 |
| IV. B.                            | 60                                  | d.                                    | i. alc.                         | d. 150                |             | 30 |

| Name.   | Formula.   | Density.        |                           |
|---|--|-----------------|---------------------------|
|   |  | Formula Weight. | Water=1<br>D : Air=1      |
| 1 Cupric arsenite   | $\text{CuHAsO}_3$  | 187.54          |                           |
| 2 — bromide   | $\text{CuBr}_2$  | 223.41          |                           |
| 3 — chlorate  | $\text{Cu}(\text{ClO}_3)_2 + 6 \text{H}_2\text{O}$                       | 338.59          |                           |
| 4 — chloride  | $\text{CuCl}_2 + 2 \text{H}_2\text{O}$                                   | 170.52          | 2.47                      |
| 5 — hydroxide   | $\text{Cu}(\text{OH})_2$   | 97.59           | 3.368                     |
| 6 — nitrate   | $\text{Cu}(\text{NO}_3)_2 + 6 \text{H}_2\text{O}$                        | 295.69          | 2.047                     |
| 7 — oxide   | $\text{CuO}$   | 79.57           | 6.304                     |
| 8 — oxychloride   | $\text{Cu}_2\text{OCl}_2$  | 214.06          |                           |
| 9 — phosphate   | $\text{Cu}_3(\text{PO}_4)_2 + 3 \text{H}_2\text{O}$                      | 434.84          |                           |
| 10 — sulphate   | $\text{CuSO}_4 + 5 \text{H}_2\text{O}$                                   | 249.71          | 2.274/15°                 |
| 11 — sulphide   | $\text{CuS}$   | 95.63           | 4.59                      |
| 12 Cuprous acetylde   | $\text{Cu}_2\text{C}_2\text{H}_2\text{O}$                                | 169.17          |                           |
| 13 — bromide  | $\text{Cu}_2\text{Br}_2$   | 286.98          | 4.72                      |
| 14 — chloride   | $\text{Cu}_2\text{Cl}_2$   | 198.06          | D. 6.6/1690°;             |
| 15 — cyanide  | $\text{Cu}_2(\text{CN})_2$   | 179.17          | 3.7                       |
| 16 — hydride  | $\text{Cu}_2\text{H}_2$  | 129.16          |                           |
| 17 — hydroxide  | $4\text{Cu}_2\text{O} + \text{H}_2\text{O}$                              | 590.58          |                           |
| 18 — iodide   | $\text{Cu}_2\text{I}_2$  | 380.98          | 5.67                      |
| 19 — oxide  | $\text{Cu}_2\text{O}$  | 143.14          | 5.8—6.1                   |
| 20 — sulphate   | $\text{Cu}_2\text{SO}_4$   | 223.20          |                           |
| 21 — sulphide   | $\text{Cu}_2\text{S}$  | 159.20          | 5.58 artif.               |
| 22 — sulphite   | $\text{Cu}_2\text{SO}_3 + \text{H}_2\text{O}$                            | 225.22          | 4.46                      |
| 23 Disulphuryl chloride   | $\text{S}_2\text{O}_5\text{Cl}_2$  | 215.04          | 1.819/20°<br>D. 7.4       |
| 24 Ferric arsenate  | $\text{FeAsO}_4 + 2 \text{H}_2\text{O}$                                  | 230.83          | 3.18                      |
| 25 — arsenite   | $4 \text{Fe}_2\text{O}_3 + \text{As}_2\text{O}_3 + 5 \text{H}_2\text{O}$ | 926.72          |                           |
| 26 — bromide  | $\text{Fe}_2\text{Br}_8$   | 591.20          |                           |
| 27 — chloride   | $\text{Fe}_2\text{Cl}_6$   | 324.44          | D : 11.2/320°;<br>2.8/11° |
| 28 — ferrocyanide<br>(Insoluble Prussian<br>blue or Turnbull's<br>blue) | $\text{Fe}_4(\text{FeC}_6\text{N}_6)_3$                                  | 859.15          |                           |
| 29 — hydroxide  | $\text{Fe}_2(\text{OH})_2$   | 213.73          | 3.4—3.9                   |

| Crystalline<br>form and<br>colour | Solubility*in                        |  | Alcohol,<br>acids<br>or alkalies          | M.P.<br>°C            | B.P.<br>°C. |    |
|-----------------------------------|--------------------------------------|--|---|-----------------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) |   |                       |             |    |
| G.                                | i.                                   |  | s. alc.                                   | d.                    |             | 1  |
| B.                                | deliq.                               |  |   | d.                    |             | 2  |
| G.                                | v.s.                                 | v.s.                                   | s. alc.                                   | 65                    | d.          | 3  |
| IV., B.                           | 121                                  | v.s.                                   | s. alc.                                   | 100                   | d. R.H.     | 4  |
| B.                                | i.                                   |  | s. $\text{NH}_4\text{OH}$                 | d.                    |             | 5  |
| B. cryst.                         | v.s.                                 | v.s.                                   | v.s.                                      | 38                    | d.          | 6  |
| I. & V., Bl.                      | i.                                   | i.                                     | i. alc.                                   |                       |             | 7  |
| Y.                                | d.                                   |  |   | d.                    |             | 8  |
| IV., B.                           | s.s.                                 | d.                                     | s. $\text{H}_3\text{PO}_4$                |                       |             | 9  |
| VI., B.                           | 40                                   | 203                                    | i. alc.                                   | 4 aq 100,<br>5 aq 240 | d. R.H.     | 10 |
| III., Bl.                         | i.                                   | i.                                     | i. alc.                                   | d.                    |             | 11 |
| Am. R.                            |                                      |  | with ac. : $\text{C}_2\text{H}_2$         | expl.                 |             | 12 |
| Br. B.                            | i.                                   |  | s. $\text{NH}_4\text{OH}$                 | 504                   | 861—894     | 13 |
| I. W.                             | v.s.s.                               |  | s. $\text{HCl}$ , $\text{NH}_4\text{OH}$  | 410                   | abt. 1000   | 14 |
| W.                                |                                      |  | s. $\text{HCl}$ , $\text{H}_2\text{SO}_4$ | R. H.                 | d.          | 15 |
|                                   | d.                                   |  | d. $\text{HCl}$                           | d. 60                 |             | 16 |
| Y.                                | i.                                   |  | s. $\text{NH}_4\text{OH}$                 | d. 360                |             | 17 |
| W. cryst.                         | i.                                   | i.                                     | s. $\text{NH}_4\text{OH}$                 | 628                   |             | 18 |
| I., R.                            | i.                                   | i.                                     | s. $\text{NH}_4\text{OH}$                 | fusible               |             | 19 |
| Gr. pdr.                          | d.                                   |  |   | oxidises<br>at 200    |             | 20 |
| IV., Bl.                          | i.                                   | i.                                     | i. alc.                                   | 1091                  |             | 21 |
| III., R.                          | s.s.                                 |  |   | d.                    |             | 22 |
|                                   | d.                                   |  |   | -39                   | 146         | 23 |
| IV., W.                           | i.                                   | i.                                     |   | d.                    |             | 24 |
| Br.                               | v.s.s.                               |  | s. $\text{HCl}$                           | d.                    |             | 25 |
| R. cryst.                         | deliq.                               | s.                                     | s. alc.                                   | d.                    | subl. & d.  | 26 |
| III., Br., Bl                     | 158                                  | 537                                    | s. alc.                                   | 301                   | 280—285     | 27 |
| Am. B.                            | i.                                   | i.                                     | s. oxalic acid                            | d.                    |             | 28 |
| R., Br.                           | i.                                   | i.                                     | i. alc., s. ac.                           | d.                    |             | 29 |

| Name.   | Formula.   | Density.        |                          |
|---|--|-----------------|--------------------------|
|   |  | Formula Weight. | Water = 1<br>D : Air = 1 |
| 1 Ferric nitrate                                    | $\text{Fe}_2(\text{NO}_3)_6 + 18 \text{H}_2\text{O}$             | 808.10          | 1.6835                   |
| 2 — oxide   | $\text{Fe}_2\text{O}_3$  | 159.68          | 5.2—5.3                  |
| 3 — phosphate                                       | $\text{Fe}(\text{PO}_4) + 2 \text{H}_2\text{O}$                  | 186.91          | 2.87                     |
| 4 — potassium ferrocyanide (Soluble Prussian blues) | $\text{KFe}(\text{FeC}_6\text{N}_6)$                             | 306.87          |                          |
| 5 — sulphate  | $\text{Fe}_2(\text{SO}_4)_3 + 9 \text{H}_2\text{O}$              | 562.00          | 2—2.1                    |
| 6 — sulphide  | $\text{Fe}_2\text{S}_3$  | 207.86          | 4.4                      |
| 7 — thiocyanate                                     | $\text{Fe}_2(\text{ONS})_6 + 6 \text{H}_2\text{O}$               | 568.23          |                          |
| 8 Ferricyanic acid                                  | $\text{H}_3\text{FeC}_6\text{N}_6$                               | 214.95          |                          |
| 9 Ferrocyanic acid                                  | $\text{H}_2\text{Fe}(\text{CN})_4$                               | 213.92          |                          |
| 10 Ferropentacarbonyl                               | $\text{Fe}(\text{CO})_5$   | 195.86          | 1.46; D 6.5              |
| 11 Ferroso-ferric oxide                             | $\text{Fe}_3\text{O}_4$  | 231.52          | 5.18 cryst.              |
| 12 Ferrotetracarbonyl                               | $\text{Fe}(\text{CO})_4$   | 167.86          | 1.996/18°                |
| 13 Ferrous ammonium sulphate                        | $\text{FeSO}_4(\text{NH}_4)_2\text{SO}_4 + 6 \text{H}_2\text{O}$ | 392.14          | 1.813                    |
| 14 — arsenate                                       | $\text{Fe}_3(\text{AsO}_4)_2 + 6 \text{H}_2\text{O}$             | 553.54          |                          |
| 15 — bromide  | $\text{FeBr}_2 + 4 \text{H}_2\text{O}$                           | 323.78          |                          |
| 16 — carbonate                                      | $\text{FeCO}_3$  | 115.84          | 3.7—3.9                  |
| 17 — chloride                                       | $\text{FeCl}_2 + 4 \text{H}_2\text{O}$                           | 198.82          | an. 2.528;<br>1.926      |
| 18 — fluoride                                       | $\text{FeF}_2 + 8 \text{H}_2\text{O}$                            | 237.97          |                          |
| 19 — hydroxide                                      | $\text{Fe}(\text{OH})_2$   | 89.86           |                          |
| 20 — iodide   | $\text{FeI}_2 + 4 \text{H}_2\text{O}$                            | 381.74          | 2.873                    |
| 21 — nitrate  | $\text{Fe}(\text{NO}_3)_2 + 6 \text{H}_2\text{O}$                | 287.96          |                          |
| 22 — oxide  | $\text{FeO}$   | 71.84           |                          |
| 23 — perchlorate                                    | $\text{Fe}(\text{ClO}_4)_2 + 6 \text{H}_2\text{O}$               | 362.86          |                          |
| 24 — phosphate                                      | $\text{Fe}_3(\text{PO}_4)_2 + 8 \text{H}_2\text{O}$              | 501.73          | 2.58—2.68                |
| 25 — platinichloride                                | $\text{FePtCl}_6$  | 463.8           | 2.714                    |
| 26 — sulphate                                       | $\text{FeSO}_4 + 7 \text{H}_2\text{O}$                           | 278.01          | 1.889                    |
| 27 — sulphide                                       | $\text{FeS}$   | 87.90           | 4.84                     |
| 28 — thiocyanate                                    | $\text{Fe}(\text{ONS})_2 + 3 \text{H}_2\text{O}$                 | 226.04          |                          |



| Crystalline<br>form and<br>colour | Solubility*in                        |  | Alcohol,<br>acids<br>or alkalis          | M.P.<br>°C.          | B.P.<br>°C. |    |
|-----------------------------------|--------------------------------------|--|--|----------------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) |  |                      |             |    |
| I.                                | s.                                   | s.                                     | s. alc.                                  | 47.2                 | d.          | 1  |
| -12 aq. I.                        |                                      |  |  |                      |             |    |
| IIa, Gr.                          | i.                                   | i.                                     | s. ac.                                   |                      |             | 2  |
|                                   | i.                                   | i.                                     | i. c. acetic                             | d.                   |             | 3  |
|                                   | i.                                   |  | d. alk. and<br>oxalic                    | d.                   |             | 4  |
| V.                                | deliq.                               | d.                                     | d. alc.                                  | d.                   |             | 5  |
|                                   | i.                                   | i.                                     | d. ac.                                   | d.                   |             | 6  |
| ., R., or Bl.                     | red s.                               | v.s.                                   | s. alc., ether                           | d.                   |             | 7  |
| Needles,<br>Gr. Br.               | deliq.                               | s.                                     | s. alc.                                  | d.                   |             | 8  |
| V. needles                        | s.                                   |  | s. alc., i. ether                        | d.                   |             | 9  |
|                                   | d.                                   |  | s. H <sub>2</sub> SO <sub>4</sub> , alc. | -21                  | 103         | 10 |
| ., Bl.                            | i.                                   | i.                                     | i. alc.                                  |                      |             | 11 |
| l. plates                         |                                      |  | s. org. solv.                            | d. 140—150           |             | 12 |
| 7.                                | 19                                   | 78/75°                                 | i. alc.                                  | d.                   |             | 13 |
| W.                                | i.                                   |  | s. s. NH <sub>4</sub> OH                 | d.                   |             | 14 |
| V., B., G.                        | s.                                   | 56.7/75°                               | s. alc.                                  | d.                   |             | 15 |
| IIa                               | i.                                   | i.                                     | s. CO <sub>2</sub> soln.                 | d.                   |             | 16 |
| 7., C.                            | deliq.                               | v.s.                                   | s. alc.                                  | R.H.                 |             | 17 |
| l.B.                              | s.                                   | s.                                     | s. HF                                    | 8 aq 100             |             | 18 |
| W.                                | v.s.s.                               |  | s. ac.                                   | d.                   |             | 19 |
| lr. cryst.                        | v.s.                                 | d.                                     | s. alc.                                  | 177                  |             | 20 |
|                                   | s.                                   | d.                                     |  | d.                   |             | 21 |
| 3l.                               | i.                                   | i.                                     | i. alc.                                  | oxidises             |             | 22 |
| l.                                | s.s.                                 |  |  | d. >100              |             | 23 |
| V., B.                            | i.                                   | i.                                     | i. ac.                                   |                      |             | 24 |
| III., Y.                          | v.s.                                 | v.s.                                   |  | d.                   |             | 25 |
| IV.; V.;                          | 20.4                                 | 42.6                                   | i. alc                                   | 6 aq 100<br>7 aq 280 | d. R.H.     | 25 |
| +5 aq. VI;<br>+4 aq. II.          |                                      |  |  |                      |             |    |
| Bl.                               | i.                                   | i.                                     | s. ac.                                   | R.H.                 |             | 27 |
| IV., G.                           | s.                                   |  | s. alc.                                  | d.                   |             | 28 |

| Name.                 | Formula   | Density.        |                      |
|-----------------------|---|-----------------|----------------------|
|                       |   | Formula Weight. | Water=1<br>D : Air=1 |
| 1 Fluorine            | F   | 19.0            |                      |
| 2 Gallium             | Ga  | 69.9            | 5.935—5.956          |
| 3 — dichloride        | GaCl <sub>2</sub>   | 140.82          | D : 4.8/1000°        |
| 4 — sulphate          | Ga <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>               | 427.98          |                      |
| 5 — trichloride       | Ga <sub>2</sub> Cl <sub>6</sub>                               | 352.6           | D : 6.1/400<br>—606° |
| 6 Germanium           | Ge  | 72.5            | 5.469/20.4°          |
| 7 — chloroform        | GeHCl <sub>3</sub>  | 179.9           |                      |
| 8 — dioxide           | GeO <sub>2</sub>  | 104.5           | 4.703/18°            |
| 9 — disulphide        | GeS <sub>2</sub>  | 136.6           |                      |
| 10 — monosulphide     | GeS   | 104.6           | D : 3.54/1100°       |
| 11 — tetrachloride    | GeCl <sub>4</sub>   | 214.3           | 1.887/18°            |
| 12 — tetra-iodide     | GeI <sub>4</sub>  | 580.2           | D : 20.5/440°        |
| 13 Glucinum           | Gl  | 9.1             | 2.1                  |
| 14 — bromide          | GlBr <sub>2</sub>   | 168.9           |                      |
| 15 — chloride         | GlCl <sub>2</sub> (+4 H <sub>2</sub> O)                       | 80.0            |                      |
| 16 — iodide           | GlI <sub>2</sub>  | 262.9           |                      |
| 17 — nitrate          | Gl(NO <sub>3</sub> ) <sub>2</sub> +3 H <sub>2</sub> O         | 187.2           |                      |
| 18 — oxide            | GlO   | 25.1            | 3.02                 |
| 19 — sulphate         | GlSO <sub>4</sub> +4 H <sub>2</sub> O                         | 177.2           | 1.725/10°            |
| 20 Gold               | Au  | 197.2           | 19.26—19.55          |
| 21 Helium             | He  | 3.99            |                      |
| 22 Hydrazine          | H <sub>2</sub> N·NH <sub>2</sub>                              | 32.05           | 1.013/15°            |
| 23 — di-hydrochloride | N <sub>2</sub> H <sub>4</sub> ·2HCl                           | 104.99          | 1.4226/20°           |
| 24 — hydrate          | H <sub>2</sub> N·NH <sub>3</sub> (OH)                         | 50.07           | 1.0305/21°           |
| 25 — sulphate         | N <sub>2</sub> H <sub>4</sub> ·H <sub>2</sub> SO <sub>4</sub> | 130.12          |                      |
| 26 Hydrazoic acid     | HN <sub>3</sub>   | 43.03           |                      |
| 27 Hydriodic acid     | HI  | 127.93          | 4.375                |
| 28 — — hydrate        | HI+xH <sub>2</sub> O (57%)                                    |                 | 1.69                 |
| 29 Hydrobromic acid   | HBr   | 80.93           | 1.78                 |
| 30 — — hydrate        | HBr+H <sub>2</sub> O (47.8%)                                  |                 | 49                   |
| 31 Hydrochloric acid  | HCl   | 36.47           | 0.929/8°             |
| 32 — — hydrate        | HCl+H <sub>2</sub> O (45.2%)                                  |                 | 1.2257               |
| 33 — — —              | HCl+8 H <sub>2</sub> O (20.18%)                               |                 | 1.101                |
| 34 Hydrocyanic acid   | HON   | 27.03           | 0.6967/18°           |

| Crystalline<br>form and<br>colour | Solubility*in                        |  |                                  | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------------------|--------------------------------------|--|----------------------------------|-------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) | Alcohol,<br>acids<br>or alkalies |             |             |    |
| Y.G.                              | d.                                   |  |                                  | -233        | -187        | 1  |
| I., W.                            | i.                                   | i.                                     | s. alk., HCl                     | 30.1        |             | 2  |
| W. cryst.                         | d.                                   |  |                                  | 164         | 535         | 3  |
| W.                                | v.s.                                 |  | s. alc.                          |             |             | 4  |
| W. needles                        | deliq., d.                           |  |                                  | 75.5        | 220         | 5  |
| I., Gr.                           | i.                                   | i.                                     | s. aq. regia                     | 960         | >1350       | 6  |
| C.                                | i.                                   | i.                                     |                                  | liq.        | 75          | 7  |
| W. pdr.                           | 0.4                                  | 7.0                                    | s. alc.                          | d.          |             | 8  |
| W. pdr.                           | 0.45                                 |  | s. KOH                           |             |             | 9  |
| IV. or V.                         | l.                                   | i.                                     | s. KOH, s.s.<br>HCl              | R.H.        |             | 10 |
|                                   | slow d.                              |  |                                  | liq.        | 86          | 11 |
| P. pdr.                           | deliq.                               | d.                                     |                                  | 144         | 350—360     | 12 |
| W.                                | i.                                   | i.                                     | s. HCl, alk                      | 1278±5      |             | 13 |
| W. needles                        | s.                                   |  | s. alc.                          | 601         | subl.       | 14 |
| C. cryst.                         | deliq.                               | v.s.                                   | s. alc.                          | 600         | subl.       | 15 |
| W. needles                        | s.                                   |  |                                  | 510         | 590         | 16 |
| Cryst.                            | deliq.                               |  |                                  | 60          | d. 200      | 17 |
| O., W.                            | i.                                   |  | s. alc.                          |             |             | 18 |
| II.;<br>+7 aq., V.                | 100/15°                              |  |                                  | 2 aq 100    | d. R.H.     | 19 |
| I.                                |                                      |  | s. aq. regia                     | 1061.0      | dist.       | 20 |
|                                   | 0.015                                |  |                                  | < -253      | -268        | 21 |
| Cryst.                            | s.                                   |  |                                  | 1.4         | 113         | 22 |
| I.                                | s.                                   | s.                                     |                                  | 198         |             | 23 |
| C.                                | m.                                   | v.s.                                   | m. alc.                          | < -40       | 118.5/740   | 24 |
| Plates.                           | s.s.                                 | v.s.                                   | s. alc.                          | 254         |             | 25 |
|                                   | m.                                   |  | s. alc.                          | -80         | 37          | 26 |
|                                   | v.s.                                 | s.                                     | s. alc.                          | -53         | -36.7/752   | 27 |
|                                   | m.                                   | m.                                     | m. alc.                          |             | 127         | 28 |
|                                   | 221                                  | 130                                    | s. alc.                          | -86         | -68.7       | 29 |
|                                   | m.                                   | m.                                     | s. alc.                          | -11         | 126         | 30 |
|                                   | 82.5/0°                              | 56/60°                                 | 327 vol. in alc.                 | -112.5      | -83.1/755   | 31 |
|                                   | m.                                   |  | s. alc.                          |             |             | 32 |
|                                   | m.                                   |  | s. alc                           |             | 110         | 33 |
|                                   | m.                                   | m.                                     | m. alc.                          | -13.8       | 26.1        | 34 |

| Name.                   | Formula.  | Density.        |                          |
|-------------------------|---|-----------------|--------------------------|
|                         |   | Formula Weight. | Water=1<br>D:Air=1       |
| 1 Hydrofluoric acid     | HF  | 20.0            | 0.9879/15°               |
| 2 — — hydrate           | HF (35.35%)   |                 | 1.15                     |
| 3 Hydrofluosilicic acid | H <sub>2</sub> SiF <sub>6</sub>                                   | 144.1           |                          |
| 4 Hydrogen              | H   | 1.008           | 0.0763 / -260°           |
| 5 — disulphide          | H <sub>2</sub> S <sub>2</sub>                                     | 66.13           | 1.71                     |
| 6 — peroxide            | H <sub>2</sub> O <sub>2</sub>                                     | 34.016          | 1.458/0°                 |
| 7 — selenide            | H <sub>2</sub> Se   | 81.2            |                          |
| 8 — sulphide            | H <sub>2</sub> S  | 34.08           | liq. 0.91/18.5           |
| 9 Hydroxylamine         | NH <sub>2</sub> OH  | 33.04           | 1.227/14°                |
| 10 — hydrochloride      | NH <sub>2</sub> OH·HCl  | 69.50           | 1.676/17°                |
| 11 — nitrate            | NH <sub>2</sub> OH·HNO <sub>3</sub>                               | 96.05           |                          |
| 12 — sulphate           | (NH <sub>2</sub> OH) <sub>2</sub> ·H <sub>2</sub> SO <sub>4</sub> | 164.16          |                          |
| 13 Hypobromous acid     | HBrO  | 96.93           |                          |
| 14 Hypochlorous acid    | HClO  | 52.47           |                          |
| 15 Hypophosphorous acid | H <sub>3</sub> PO <sub>2</sub>                                    | 66.06           | 1.49/10°                 |
| 16 Indium               | In  | 114.8           | 7.42                     |
| 17 — chloride           | InCl <sub>3</sub>   | 221.2           |                          |
| 18 — oxide              | In <sub>2</sub> O <sub>3</sub>                                    | 277.6           | 7.18                     |
| 19 — sulphide           | In <sub>2</sub> S <sub>3</sub>                                    | 325.8           |                          |
| 20 Iodic acid           | HIO <sub>3</sub>  | 175.93          | 4.629/0°                 |
| 21 Iodine               | I   | 126.92          | 4.933                    |
| 22 — monochloride       | ICl   | 162.38          | 3.222 ;<br>D : 80.3/120° |
| 23 — pentoxide          | I <sub>2</sub> O <sub>5</sub>                                     | 333.84          | 4.487/0°                 |
| 24 — trichloride        | ICl <sub>3</sub>  | 233.30          | 3.11                     |
| 25 Iridium              | Ir  | 193.1           | 21.15/17.5°              |
| 26 — sesquioxide        | Ir <sub>2</sub> O <sub>3</sub>                                    | 434.2           |                          |
| 27 — tetrabromide       | IrBr <sub>4</sub>   | 512.8           |                          |
| 28 — tetrachloride      | IrCl <sub>4</sub>   | 334.9           |                          |
| 29 — tetra-iodide       | IrI <sub>4</sub>  | 700.8           |                          |
| 30 — trichloride        | Ir <sub>2</sub> Cl <sub>6</sub>                                   | 599.0           |                          |
| 31 Iron, cast-iron      | Fe  | 55.84           | 7—7.6                    |
| 32 —, wrought-iron      |   |                 | 7.25—7.79                |
| 33 —, steel             |   |                 | 7.6—7.8                  |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       | Alcohol,<br>acids<br>or alkalies | M.P.<br>°C.              | B.P.<br>°C. |                |
|-----------------------------------|-------------------------------------|---------------------------------------|----------------------------------|--------------------------|-------------|----------------|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) |                                  |                          |             |                |
|                                   | 111/35°                             | v.s.                                  |                                  | -92.3                    | 19.4        | 1              |
|                                   | v.s.                                | v.s.                                  |                                  |                          | 120         | 2              |
| C.                                | s.                                  |                                       | s.s. alk.                        |                          | d.          | 3              |
|                                   | 1.93 vol.                           |                                       | alc. 6.925/0°                    | -257                     | -253        | 4              |
|                                   | i.                                  |                                       | i                                | liq.                     | d.          | 5              |
| C.                                | m.                                  |                                       | s. ether                         | -2                       | 84/68 mm.   | 6              |
|                                   | v.s.                                |                                       | s. COCl <sub>2</sub>             | -64                      | -42         | 7              |
|                                   | 1:3.23<br>vol. at 15°               | 1:1.86<br>vol. at 40°                 | alc. 9.54/15°                    | -86                      | 61.6        |                |
| W. needles                        | deliq.                              | d.                                    | i. ether                         | 33                       | 70/60 mm.   | 9              |
| V.                                | s.                                  |                                       | s.s. alc.                        | 151                      | d.          | 10             |
| W.                                | v.s.                                | d.                                    | v.s. alc.                        | -10                      | d. <100     | 11             |
| V.                                | s.                                  | s.                                    | s.s. alc.                        | 140                      | d.          | 12             |
| C.                                | s.                                  | s.                                    |                                  |                          | 40 in vac.  | 13             |
| Y.                                | 100 vol./0°                         | s.                                    | d. HCl                           |                          | d.          | 14             |
|                                   | deliq.                              | v.s.                                  |                                  | 17.4                     | d.          | 15             |
| W.                                | i.                                  | i.                                    | s. HNO <sub>3</sub>              | 176                      |             | 16             |
| W.                                | deliq.                              |                                       |                                  |                          | 440         | 17             |
| Y.                                |                                     |                                       |                                  |                          |             | 18             |
| Br.                               |                                     |                                       |                                  |                          |             | 19             |
| IV.                               | 187                                 | v.s.                                  |                                  | $\frac{1}{2}$ aq 170     |             | 20             |
| Bl.                               | v.s.s.                              | v.s.s.                                | s. alc.                          | 114                      | 184         | 21             |
| R.                                | slight d.                           |                                       | s. HCl                           | 25                       | d. 101      | 22             |
| W.                                | s.                                  | s.                                    |                                  | d. 300                   |             | 23             |
| Y. cryst.                         | s. d.                               |                                       | s. acetic                        | 101/16atm                | d. 25       | 24             |
| Gr.                               | i.                                  |                                       | i.                               | 2300 ?                   |             | 25             |
| Bl.                               | i.                                  |                                       |                                  | d. 1000                  |             | 26             |
| B.                                | s.                                  |                                       | s. alc.                          | d.                       |             | 27             |
| Bl.                               | s.                                  | s.d.                                  | s. alc.                          | d.                       |             | 28             |
| Bl.                               | i.                                  | i.                                    | i. ac., s. KI                    | d. 360                   |             | 29             |
| Y.G.                              | i.                                  |                                       | i.                               |                          |             | 30             |
| Gr.                               | i.                                  | i.                                    | s. ac.                           | { 1050<br>1545<br>1300 } |             | 31<br>32<br>33 |

| Name.                    | Formula.   | Density.        |                             |
|--------------------------|--|-----------------|-----------------------------|
|                          |  | Formula Weight. | Water=1<br>D:Air=1          |
| 1 Iron carbide           | $\text{Fe}_3\text{C}$                              | 179.53          |                             |
| 2 — disulphide           | $\text{FeS}_2$                                     | 119.96          | 5.185; mineral<br>4.68—4.85 |
| 3 — oxide, magnetic      | $\text{Fe}_3\text{O}_4$                            | 231.52          | 5.18                        |
| 4 — phosphide            | $\text{FeP}$                                       | 142.76          | 6.57                        |
| 5 Lanthanum chloride     | $\text{LaCl}_3$                                    | 245.4           | 3.95/18°                    |
| 6 — oxide                | $\text{La}_2\text{O}_3$                            | 326.0           | 6.48                        |
| 7 — sulphate             | $\text{La}_2(\text{SO}_4)_3 + 9\text{H}_2\text{O}$ | 728.3           |                             |
| 8 Lead                   | $\text{Pb}$  | 207.2           | 11.35—11.387                |
| 9 — borate               | $\text{Pb}(\text{BO}_2)_2 + \text{H}_2\text{O}$    | 311.0           | 5.598 an.                   |
| 10 — bromide             | $\text{PbBr}_2$                                    | 367.0           | 6.611                       |
| 11 — carbonate           | $\text{PbCO}_3$                                    | 267.2           | 6.465                       |
| 12 — — (white lead)      | $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$      | 775.6           |                             |
| 13 — chlorate            | $\text{Pb}(\text{ClO}_3)_2$                        | 374.1           | 4.037                       |
| 14 — chloride            | $\text{PbCl}_2$                                    | 278.1           | 5.8                         |
| 15 — chlorite            | $\text{Pb}(\text{ClO}_2)_2$                        | 342.1           |                             |
| 16 — chromate            | $\text{PbCrO}_4$                                   | 323.2           | 6.123/15°                   |
| 17 — cyanate             | $\text{Pb}(\text{CNO})_2$                          | 291.2           |                             |
| 18 — cyanide             | $\text{Pb}(\text{CN})_2$                           | 259.2           |                             |
| 19 — dioxide             | $\text{PbO}_2$                                     | 239.2           | 8.9—9.39—9.54               |
| 20 — fluoride            | $\text{PbF}_2$                                     | 245.2           | 8.241                       |
| 21 — hydroxide           | (a) $\text{Pb}(\text{OH})_2$                       | 241.2           |                             |
| 22 — —                   | (b) $3\text{PbO} \cdot \text{H}_2\text{O}$         | 687.6           |                             |
| 23 — iodide              | $\text{PbI}_2$                                     | 461.0           | 6.12                        |
| 24 — monoxide (massicot) | $\text{PbO}$                                       | 223.2           | 9.29                        |
| 25 — — (litharge)        | $\text{PbO}$                                       | 223.2           | 8.74—9.0                    |
| 26 — — (amorph.)         | $\text{PbO}$                                       | 223.2           | 9.2—9.5                     |
| 27 — nitrate             | $\text{Pb}(\text{NO}_3)_2$                         | 331.2           | 4.53/20°                    |
| 28 — oxychloride         | $\text{PbCl}_2 \cdot \text{PbO}$                   | 501.3           | 7.21                        |
| 29 — —                   | $\text{PbCl}_2 \cdot 2\text{PbO}$                  | 724.5           | 7.08                        |
| 30 — phosphate, ortho    | $\text{Pb}_2(\text{PO}_4)_2$                       | 811.7           | 6.9—7.3                     |
| 31 — — pyro              | $\text{Pb}_2\text{P}_2\text{O}_7$                  | 588.5           | 5.8                         |
| 32 — sesquioxide         | $\text{Pb}_2\text{O}_3$                            | 462.4           |                             |
| 33 — suboxide            | $\text{Pb}_2\text{O}$                              | 430.4           |                             |
| 34 — sulphate            | $\text{PbSO}_4$                                    | 303.3           | 6.2—6.38                    |
| 35 — — (acid)            | $\text{PbH}_2(\text{SO}_4)_2 + \text{H}_2\text{O}$ | 419.4           |                             |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       | Alcohol,<br>acids<br>or alkalies | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------------------|-------------------------------------|---------------------------------------|----------------------------------|-------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) |                                  |             |             |    |
| Bl.                               | i.                                  | i.                                    | i. dil. ac.                      |             |             | 1  |
| Y.                                | i.                                  | i.                                    | s. $\text{HNO}_3$<br>ppts. S.    | d.          |             | 2  |
| I., Bl.                           | i.                                  | i.                                    | i. alc., s. $\text{HCl}$         |             |             | 3  |
| G.                                | i.                                  | i.                                    | s. ac. and d.                    | infusible   |             | 4  |
| Cryst.                            | v.s.                                | v.s.                                  | v.s. alc.                        | 907         |             | 5  |
| W. pdr.                           | gives<br>$\text{La}(\text{OH})_3$   |                                       |                                  |             |             | 6  |
| O. cryst.                         | 17 (3°)                             | 0.85                                  | s.s. $\text{HCl}$                | d.          |             | 7  |
| I., Gr. W.                        | i.                                  |                                       | s. $\text{HNO}_3$                | 327.4       | 1470        | 8  |
| W., pdr.                          | i.                                  | i.                                    | i. alc.                          | R.H.        | aq 160      | 9  |
| C. needles                        | s.s.                                | s.                                    | i. alc.                          | d. 448      |             | 10 |
| IV. W.                            | 0.00198                             | i.                                    | i. alc., s. ac.                  | d.          |             | 11 |
| Am. W.                            | i.                                  |                                       |                                  | d.          |             | 12 |
| V., W.                            | s.                                  | s.                                    |                                  | d. 230      |             | 13 |
| IV.                               | 0.909                               | 3.2                                   | s. alk.                          | 447         | 900         | 14 |
| V., Y.                            | s.s.                                | s.                                    |                                  | expl. > 100 |             | 15 |
| V., Y.                            | i.                                  | i.                                    | s. alk., s.s. ac.                | fusible     |             | 16 |
| W. needles                        | s.s.                                | s.                                    |                                  | d.          |             | 17 |
| W.                                | i.                                  |                                       | i. $\text{KCN}$ soln.            |             |             | 18 |
| III., Br.                         | i.                                  | i.                                    | i. alc.                          | d.          |             | 19 |
| W.                                | i.                                  | i.                                    | s. $\text{HCl}$ , $\text{HNO}_3$ | fusible     |             | 20 |
| W.                                | v.s.s.                              | v.s.s.                                | s. alk.                          | d. 145      |             | 21 |
| I., W.                            |                                     |                                       |                                  | aq 130      |             | 22 |
| Y., cryst.                        | 0.081                               | 0.515                                 | i. alc., s. $\text{KI}$          | 375         | 861—954     | 23 |
| IV., Y.                           | i.                                  | i.                                    | s. alk.                          | R.H.        |             | 24 |
| III., R.                          | i.                                  | i.                                    |                                  |             |             | 25 |
| Am. Y.                            |                                     |                                       |                                  | R.H.        |             | 26 |
| I. W.                             | 48.4                                | 127                                   | s. alk.                          | d.          |             | 27 |
| II.                               |                                     |                                       |                                  | d. 524      |             | 28 |
| IV. Br.                           |                                     |                                       | s. alk.                          | 693         |             | 29 |
| W.                                | i.                                  | i.                                    |                                  | fusible     |             | 30 |
| IV., W.                           | i.                                  |                                       | s. alk., $\text{HNO}_3$          |             |             | 31 |
| Am. Y.                            | i.                                  | i.                                    | i. alk.                          | d.          |             | 32 |
| Bl.                               | d.                                  |                                       | d. alk.                          | d.          |             | 33 |
| IV.                               | 0.004                               | s.s.                                  | i. alc., s. alk.                 | 937         |             | 34 |
| Cryst                             | v.s.s.                              |                                       |                                  | d.          |             | 35 |

| Name.                   | Formula.  | Density.        |                          |
|-------------------------|---|-----------------|--------------------------|
|                         |   | Formula Weight. | Water=1<br>D:Air=1       |
| 1 Lead sulphate (basic) | $\text{PbSO}_4 \cdot \text{PbO}$                                    | 526.5           |                          |
| 2 — sulphide            | $\text{PbS}$  | 239.3           | 7.25—7.7                 |
| 3 — tetrachloride       | $\text{PbCl}_4$   | 349.0           | 3.18/0°                  |
| 4 Lithium               | $\text{Li}$   | 6.94            | 0.5936                   |
| 5 — bromide             | $\text{LiBr}$   | 86.86           | 3.464/25°                |
| 6 — carbide             | $\text{Li}_2\text{C}_2$   | 37.89           | 1.65/18°                 |
| 7 — carbonate           | $\text{Li}_2\text{CO}_3$  | 73.88           | 2.111                    |
| 8 — chlorate            | $2\text{LiClO}_3 + \text{H}_2\text{O}$                              | 198.82          |                          |
| 9 — chloride            | $\text{LiCl} + 2\text{H}_2\text{O}$                                 | 78.43           | 2.068/25°                |
| 10 — fluoride           | $\text{LiF}$  | 25.94           | 2.54                     |
| 11 — hydride            | $\text{LiH}$  | 7.95            |                          |
| 12 — hydroxide          | $\text{LiOH}$   | 23.95           |                          |
| 13 — iodide             | $\text{LiI} + 3\text{H}_2\text{O}$                                  | 187.91          | 3.48                     |
| 14 — nitrate            | $\text{LiNO}_3$   | 68.95           | 2.334/92.5°              |
| 15 — oxide              | $\text{Li}_2\text{O}$   | 29.88           | 2.10/15°                 |
| 16 — perchlorate        | $\text{LiClO}_4 + 3\text{H}_2\text{O}$                              | 160.45          |                          |
| 17 — phosphate          | $2\text{Li}_3\text{PO}_4 + \text{H}_2\text{O}$                      | 249.74          | 2.41                     |
| 18 — platinichloride    | $\text{Li}_2\text{PtCl}_6 + 6\text{H}_2\text{O}$                    | 529.9           |                          |
| 19 — sulphate           | $\text{Li}_2\text{SO}_4 + \text{H}_2\text{O}$                       | 127.96          | 2.02                     |
| 20 — sulphite           | $\text{Li}_2\text{SO}_3 + \text{H}_2\text{O}$                       | 111.96          |                          |
| 21 Magnesium            | $\text{Mg}$   | 24.32           | 1.75                     |
| 22 — bromate            | $\text{Mg}(\text{BrO}_3)_2 + 6\text{H}_2\text{O}$                   | 388.26          | 2.29                     |
| 23 — bromide            | $\text{MgBr}_2 + 6\text{H}_2\text{O}$                               | 292.26          |                          |
| 24 — carbonate          | $\text{MgCO}_3$   | 84.32           | 3.056                    |
| 25 — — (basic)          | $3\text{MgCO}_3 \cdot \text{Mg}(\text{OH})_2 + 3\text{H}_2\text{O}$ | 365.37          | 2.18                     |
| 26 — chlorate           | $\text{Mg}(\text{ClO}_3)_2 + 6\text{H}_2\text{O}$                   | 299.34          |                          |
| 27 — chloride           | $\text{MgCl}_2 + 6\text{H}_2\text{O}$                               | 203.34          | 1.558/17°                |
| 28 — fluoride           | $\text{MgF}_2$  | 62.32           | 2.97                     |
| 29 — hydrogen phosphate | $\text{MgHPO}_4 + 7\text{H}_2\text{O}$                              | 246.48          |                          |
| 30 — hydroxide          | $\text{Mg}(\text{OH})_2$  | 58.34           | 2.34                     |
| 31 — iodate             | $\text{Mg}(\text{IO}_3)_2 + 4\text{H}_2\text{O}$                    | 446.22          | 3.28                     |
| 32 — iodide             | $\text{MgI}_2$  | 278.14          |                          |
| 33 — nitrate            | $\text{Mg}(\text{NO}_3)_2 + 6\text{H}_2\text{O}$                    | 256.44          | 1.46                     |
| 34 — oxide              | $\text{MgO}$  | 40.32           | 3.36 cryst.:<br>3.58 am. |



| Crystalline<br>form and<br>colour | Solubility*in                       |                                       |                                  | M.P.<br>°C.  | B.P.<br>°C. |    |
|-----------------------------------|-------------------------------------|---------------------------------------|----------------------------------|--------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) | Alcohol,<br>acids<br>or alkalies |              |             |    |
| W.                                | 1:22816                             | v.s.s.                                | s.s. $\text{H}_2\text{SO}_4$     | d.           |             | 1  |
| I.                                | i.                                  | i.                                    | i. alc.                          | R.H.         | subl.       | 2  |
|                                   | d.                                  |                                       |                                  | -15          | d. 105      | 3  |
|                                   | d.                                  |                                       | d. alc.                          | 186          | >950        | 4  |
| Cryst.                            | 143/0°                              | 270/103°                              |                                  | 442          |             | 5  |
| W. pdr.                           | d.                                  |                                       |                                  |              |             | 6  |
| W.                                | 1.37                                | 0.728                                 | i. alc.                          | 618          |             | 7  |
| II.                               | deliq.                              |                                       | v.s. alc.                        | 50           | aq 90       | 8  |
| II., an. I.                       | 76.5                                | 125                                   | v.s. alc.                        | 606          | d. W.H.     | 9  |
| O.                                | 0.27 (14°)                          |                                       |                                  | R.H.         |             | 10 |
| W.                                | d.                                  |                                       |                                  | 680          |             | 11 |
| W.                                | s.s.                                |                                       |                                  | R.H.         |             | 12 |
| V.                                | 164                                 | 476                                   |                                  | 72           | aq 120      | 13 |
| IIIa                              | 55.2                                | 227.3                                 | v.s. alc.                        | 258          |             | 14 |
| W.                                | 5 (0°)                              | s.                                    |                                  | vol. 600     |             | 15 |
| IIIa                              | deliq.                              | s.                                    | s. alc.                          | 2 aq 100     |             | 16 |
|                                   | 0.04                                |                                       | s. ac.                           | 3 aq 150     |             | 17 |
| III., Y.                          | s.                                  | s.                                    | s. alc.                          | aq 180       |             | 18 |
| V.                                | 34.6/18°                            | 29.2                                  | s. alc.                          | an. 853      |             | 19 |
| Needles                           | s.                                  |                                       | s.s. alc.                        | R.H.         |             | 20 |
| W.                                | i.                                  | d. steam                              | s. ac.                           | 750          | 1100        | 21 |
| I.                                | 71.4                                |                                       |                                  | 6 aq 200     | d.          | 22 |
| III.                              | 103.4 (18°)                         | v.s.                                  |                                  | 165          | d.          | 23 |
| IIIa, IV                          | i.                                  | i.                                    | s. $\text{CO}_2$ soln.           | d. 350       |             | 24 |
| V.                                | v.s.s.                              | v.s.s.                                |                                  | d.           |             | 25 |
| W. cryst.                         | deliq.                              | s.                                    | s. alc.                          | 40           | d. 120      | 26 |
| V.                                | 54                                  | v.s.                                  | s. alc.                          | d. >186      |             | 27 |
| II.                               | 0.076/18°                           |                                       | i. ac.                           |              |             | 28 |
| III.                              | s.s.                                |                                       | s. ac.                           | 4 aq 100     |             | 29 |
| IIIa                              | 0.0009(18°)                         |                                       | s. $\text{NH}_4\text{Cl}$        | d.           |             | 30 |
| V.                                | 10.6                                | 33                                    |                                  | 4 aq 210     | d.          | 31 |
| W. cryst.                         | 148 (18°)                           |                                       | s. alc.                          | fusible      |             | 32 |
| V., VI.                           | 73.4 (18°)                          |                                       | s. alc.                          | 90, 5 aq 100 | d.          | 33 |
| I.                                | s.                                  |                                       | s. alc.                          | 2250         |             | 34 |

| Name.                      | Formula.  | Density.        |                         |
|----------------------------|---|-----------------|-------------------------|
|                            |   | Formula Weight. | Water=1<br>D:Air=1      |
| 1 Magnesium pyrophosphate  | $\text{Mg}_2\text{P}_2\text{O}_7 + 3\text{H}_2\text{O}$ | 276.77          | 2.56                    |
| 2 — sulphate (epsomite)    | $\text{MgSO}_4 + 7\text{H}_2\text{O}$                   | 246.50          | 1.678/16°               |
| 3 — — (kieserite)          | $\text{MgSO}_4 + \text{H}_2\text{O}$                    | 138.40          | 2.35                    |
| 4 — sulphide               | $\text{MgS}$  | 56.38           | 2.85 cryst.;<br>2.2 am. |
| 5 — sulphite               | $\text{MgSO}_3 + 6\text{H}_2\text{O}$                   | 212.48          |                         |
| 6 Manganese                | $\text{Mn}$   | 54.93           | 8.0                     |
| 7 — dioxide                | $\text{MnO}_2$  | 86.93           | 4.82                    |
| 8 — heptoxide              | $\text{Mn}_2\text{O}_7$                                 | 221.86          |                         |
| 9 — tetrachloride          | $\text{MnCl}_4$   | 196.77          |                         |
| 10 — tetrafluoride         | $\text{MnF}_4$  | 130.93          |                         |
| 11 — trioxide              | $\text{MnO}_3$  | 102.93          |                         |
| 12 Manganic meta-phosphate | $\text{Mn}_2(\text{PO}_3)_6 + 2\text{H}_2\text{O}$      | 620.13          | 4.75 cryst.;            |
| 13 — oxide                 | $\text{Mn}_2\text{O}_3$                                 | 157.86          | 4.32 am.                |
| 14 — — hydrated            | $\text{Mn}_2\text{O}_3(\text{OH})_2$                    | 175.88          | 4.33                    |
| 15 — sulphate              | $\text{Mn}_2(\text{SO}_4)_3$                            | 398.04          |                         |
| 16 Mangano-manganic oxide  | $\text{Mn}_3\text{O}_4$                                 | 228.79          | 4.72—4.85 cryst.        |
| 17 Manganous carbonate     | $\text{MnCO}_3$   | 114.93          | 3.45—3.60 nat.          |
| 18 — chloride              | $\text{MnCl}_2 + 4\text{H}_2\text{O}$                   | 197.91          | 1.91                    |
| 19 — hydroxide             | $\text{Mn}(\text{OH})_2$                                | 88.95           | 3.26                    |
| 20 — iodide                | $\text{MnI}_2 + 4\text{H}_2\text{O}$                    | 380.83          |                         |
| 21 — nitrate               | $\text{Mn}(\text{NO}_3)_2 + 6\text{H}_2\text{O}$        | 287.05          | 1.82/21°                |
| 22 — oxide                 | $\text{MnO}$  | 70.93           | 5.09                    |
| 23 — sulphate              | $\text{MnSO}_4 + 4\text{H}_2\text{O}$                   | 223.05          | 2.107/4°                |
| 24 — sulphate              | $\text{MnSO}_4 + 7\text{H}_2\text{O}$                   | 277.10          | 3.1 an.                 |
| 25 — sulphide              | $\text{MnS} (+\text{H}_2\text{O})$                      | 87.00           | 4.04                    |
| 26 Mercuric acetylde       | $3\text{C}_2\text{Hg}, \text{H}_2\text{O}$              | 691.8           | 5.3                     |

| Crystalline<br>form and<br>colour | Solubility*in                        |  | Alcohol,<br>acids<br>or alkalis   | M.P.<br>°C.                       | B.P.<br>°C.          |    |
|-----------------------------------|--------------------------------------|--|-----------------------------------|-----------------------------------|----------------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) |                                   |                                   |                      |    |
| Am. W.                            | i.                                   | i.                                     | i. alc                            | 5 aq 150                          |                      | 1  |
| IV., V.                           | 33.8                                 | 73.8                                   | s. alc                            | 6 aq 150<br>7 aq 200              |                      | 2  |
| IV.                               | v.s.s.                               | s.                                     |                                   |                                   |                      | 3  |
| Am. Br.                           | s.s.                                 | d.                                     |                                   | d.                                |                      | 4  |
| III.                              | 1.25                                 | 0.83                                   |                                   | 6 aq 260                          |                      | 5  |
| Gr                                | slow d.                              | d.                                     | s. ac.                            | 1225                              |                      | 6  |
| IV., Gr.                          | i.                                   | i.                                     | with HCl : Cl                     | d. 390                            |                      | 7  |
| Bl.                               | s. d.                                |  | s. H <sub>2</sub> SO <sub>4</sub> | liq.                              | expl. 70             | 8  |
|                                   | s. to green                          | s.                                     | s. ether <sup>4</sup>             |                                   |                      | 9  |
|                                   | s. to brown                          | d.                                     |                                   |                                   |                      | 10 |
| Bl.                               | HMnO <sub>4</sub>                    |  | s. alk.                           | liq.                              | 50                   | 11 |
| P.                                | s.s.                                 | s.                                     |                                   |                                   |                      | 12 |
| II., Br.                          | i.                                   | i.                                     | i. acetic                         |                                   |                      | 13 |
| II., Bl. Br.                      | i.                                   | i.                                     | s. ac.                            | to Mn <sub>2</sub> O <sub>4</sub> |                      | 14 |
| G.                                | d.                                   |  |                                   | d. 160 <sup>3 4</sup>             |                      | 15 |
| II., R.                           | i.                                   | i.                                     | s. ac. d.                         |                                   |                      | 16 |
| IIIa, P.                          | i.                                   | i.                                     | i. alc., s. ac.                   | d.                                |                      | 17 |
| V., P.                            | 107 (10°)                            | 116                                    | s. alc.                           | 2 aq 58<br>4 aq 198               |                      | 18 |
| W.                                | i.                                   | i.                                     | s. ac.                            | d.                                |                      | 19 |
| C. needles                        | deliq.                               | v.s.                                   |                                   |                                   |                      | 20 |
| V., W.                            | v.s.                                 | v.s.                                   | s. alc.                           | +6 aq 25.8                        | d. 230               | 21 |
|                                   |                                      |  |                                   | +3 aq 35.5                        |                      |    |
| I., G.                            | i.                                   | i.                                     | s. ac.                            | W.H.                              |                      | 22 |
| V                                 | 63.8                                 | 52.9                                   | i. alc.                           | stable<br>18—30                   |                      | 23 |
| IV., V.                           | 64.3                                 | 33.2                                   | i. alc.                           | 54<br>an. 400                     | 5 aq 120<br>6 aq 200 | 24 |
| I., G.; Am. F.                    | i.                                   | i.                                     | s. alc.                           | fusible                           |                      | 25 |
| W. pdr.                           | i.                                   | i.                                     | i. alc.                           | expl.                             |                      | 26 |

| Name.                | Formula.  | Density.        |                        |
|----------------------|---|-----------------|------------------------|
|                      |   | Formula Weight. | Water=1<br>D:Air=1     |
| 1 Mercuric bromide   | $\text{HgBr}_2$                                 | 360.4           | 5.7                    |
| 2 — chloride         | $\text{HgCl}_2$                                 | 271.5           | 5.403; D:9.8           |
| 3 — cyanide          | $\text{HgC}_2\text{N}_2$                        | 252.6           | 3.99—4.02              |
| 4 — iodide           | $\text{HgI}_2$                                  | 454.4           | 6.26                   |
| 5 — potassium iodide | $2\text{KHgI}_3(+3\text{H}_2\text{O})$          | 1294.9          | 4.25                   |
| 6 — nitrate          | $\text{Hg}(\text{NO}_3)_2$                      | 324.6           |                        |
| 7 — oxide            | $\text{HgO}$                                    | 216.6           | 11.136/4°              |
| 8 — sulphate         | $\text{HgSO}_4(+2\text{H}_2\text{O})$           | 296.7           | 6.47                   |
| 9 — — (basic)        | $\text{HgSO}_4+2\text{HgO}$                     | 729.9           | 6.444                  |
| 10 — sulphide        | $\text{HgS}$                                    | 232.7           | 8.124                  |
| 11 Mercurous bromide | $\text{Hg}_2\text{Br}_2$                        | 561.0           | 7.037                  |
| 12 — carbonate       | $\text{Hg}_2\text{CO}_3$                        | 461.2           | D, 3.92/218°           |
| 13 — chloride        | $\text{Hg}_2\text{Cl}_2$                        | 472.1           | 6.48                   |
| 14 — chromate        | $\text{Hg}_2\text{CrO}_4$                       | 517.2           |                        |
| 15 — iodide          | $\text{Hg}_2\text{I}_2$                         | 655.0           | 7.644                  |
| 16 — nitrate         | $\text{Hg}_2(\text{NO}_3)_2$                    | 525.2           | liq. :4.3/70°          |
| 17 — oxide           | $\text{Hg}_2\text{O}$                           | 417.2           | 8.95                   |
| 18 — sulphate        | $\text{Hg}_2\text{SO}_4$                        | 497.3           | 7.12 ppd.              |
| 19 Mercury           | $\text{Hg}$                                     | 200.6           | 13.59;<br>D:6.93/18.5° |
| 20 Microcosmic salt  | $\text{NH}_4\text{NaHPO}_4+4\text{H}_2\text{O}$ | 209.15          | 1.55                   |
| 21 Molybdenum        | $\text{Mo}$                                     | 96.0            | 9.01                   |
| 22 — dichloride      | $\text{MoCl}_2$                                 | 166.9           |                        |
| 23 — dioxide         | $\text{MoO}_2$                                  | 128.0           | 6.44/16°               |
| 24 — disulphide      | $\text{MoS}_2$                                  | 160.1           | 4.88                   |
| 25 — hexafluoride    | $\text{MoF}_6$                                  | 210.0           |                        |
| 26 — pentachloride   | $\text{MoCl}_5$                                 | 273.3           | D:9.5/350°             |
| 27 — tetrasulphide   | $\text{MoS}_4$                                  | 224.2           |                        |
| 28 — trioxide        | $\text{MoO}_3$                                  | 144.0           | 4.39/21°               |
| 29 — trisulphide     | $\text{MoS}_3$                                  | 192.2           |                        |
| 30 Molybdic acid     | $\text{H}_2\text{MoO}_4+4\text{H}_2\text{O}$    | 234.08          |                        |
| 31 Nickel            | $\text{Ni}$                                     | 58.68           | 8.8—8.9                |
| 32 — bromide         | $\text{NiBr}_2+3\text{H}_2\text{O}$             | 272.57          |                        |
| 33 — chloride        | $\text{NiCl}_2$                                 | 129.60          | 2.56                   |

| Crystalline<br>form and<br>colour | Solubility*in—                       |  |  | M.P.<br>°C. | B.P.<br>°C. |        |
|-----------------------------------|--------------------------------------|--|--|-------------|-------------|--------|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) | Alcohol,<br>acids<br>or alkalies                     |             |             |        |
| IV., W.                           | 0.4                                  |  | s. alc.  | 244         | 319         | 1      |
| IV.                               | 5.6                                  | 55.7                                   | 33 alc. 25 ether<br>s. NaCl aq.                      | 287         | 303—307     | 2      |
| II.                               | 12                                   | 53.8                                   | 5 alc.   | d.          |             | 3      |
| II., R.,<br>IV., Y.               | 0.003                                | s.s.                                   | 0.8 alc.   | 241         | 349         | 4      |
| Y.                                | s. forms<br>basic salt               | s.                                     | s. alc., acetic<br>s. HNO <sub>3</sub>               | d.<br>79    | d. R.H.     | 5<br>6 |
| R. & Y.                           | 0.005                                | v.s.s.                                 | i. alc.  | d. R.H.     |             | 7      |
| W.                                | forms<br>basic salt                  |  | i. alc.  | d. R.H.     |             | 8      |
| Y.                                | 0.05                                 | 0.33                                   | i. alc.  | turns red   |             | 9      |
| IIIa, R.;<br>Am Bl.               | i.                                   | i.                                     | s. aqua regia.                                       | subl.       |             | 10     |
| II., W.                           | i.                                   | i.                                     |  | subl. 350   |             | 11     |
| Y.                                | i.                                   | i.                                     | i. alc.  | d. 130      |             | 12     |
| IV., W.                           | i.                                   | i.                                     | i. alc.  | 302         | subl        | 13     |
| R. needles                        | i.                                   | i.                                     | i. alc.  | d.          |             | 14     |
| IV., G.                           | s.s.                                 | i.                                     | i. alc.  | 290         | 310         | 15     |
| 2 aq. V.                          | forms<br>basic salt                  |  | s. dil. HNO <sub>3</sub>                             | 70          | d.          | 16     |
| Bl.                               | i.                                   | i.                                     | i. alc.  |             |             | 17     |
| V.                                | v.s.s.                               | d.                                     | s. hot. H <sub>2</sub> SO <sub>4</sub>               | d.          |             | 18     |
| W.                                | i.                                   |  | s. HNO <sub>3</sub> , H <sub>2</sub> SO <sub>4</sub> | —38.9       | 357.25      | 19     |
| V.C.                              | 16                                   | 100                                    | i. alc.  | d.          |             | 20     |
| W.                                |                                      |  | s. HNO <sub>3</sub> , i. HCl                         | 2420—2480   |             | 21     |
| Y.                                | i.                                   | i.                                     | s. alc., s. HCl                                      | subl.       |             | 22     |
| II., Br. Bl.                      | i.                                   | i.                                     | i. aq. KOH   |             |             | 23     |
| Bl. pdr.                          |                                      |  |  |             |             | 24     |
| W. cryst.                         | d.                                   |  |  | 17          | 35          | 25     |
| Bl.                               | d.                                   |  | s. alc., s. HCl                                      | 194         | 268         | 26     |
| Br.                               | i.                                   |  | s. KHS   |             |             | 27     |
| IV., W. pd.                       | 0.2                                  | 0.1                                    | s. NH <sub>4</sub> OH                                | 759         | d.          | 28     |
| Br.                               | s.s.                                 |  | s. KHS   | d.          |             | 29     |
| Y.                                | s.                                   | s.                                     | s. ac.   |             |             | 30     |
| W.                                | i.                                   |  | s. ac.   | 1452        |             | 31     |
| Needles                           | deliq.                               | v.s.                                   |  |             |             | 32     |
| Y.                                | s.                                   | s.                                     | s. alc.  | subl.       |             | 33     |

| Name.                      | Formula.  | Density.        |                          |
|----------------------------|---|-----------------|--------------------------|
|                            |   | Formula Weight. | Water=1<br>D : Air=1     |
| 1 Nickel chloride, hydrate | $\text{NiCl}_2 + 6 \text{H}_2\text{O}$              | 237.70          |                          |
| 2 Nickel hydroxide         | $\text{Ni}(\text{OH})_2$                            | 219.41          |                          |
| 3 Nickel nitrate           | $\text{Ni}(\text{NO}_3)_2 + 6 \text{H}_2\text{O}$   | 290.80          | 2.065/14°                |
| 4 — phosphate              | $\text{Ni}_3(\text{PO}_4)_2 + 7 \text{H}_2\text{O}$ | 492.23          |                          |
| 5 — cyanide                | $\text{NiC}_2\text{N}_2$                            | 110.71          |                          |
| 6 — hydroxide              | $\text{Ni}(\text{OH})_2$                            | 92.70           | 4.36                     |
| 7 — oxide                  | $\text{NiO}$  | 74.68           | 6.4—6.8                  |
| 8 — phosphide              | $\text{Ni}_3\text{P}_2$                             | 238.12          | 5.99                     |
| 9 — sesquioxide            | $\text{Ni}_2\text{O}_3$                             | 165.36          | 4.846                    |
| 10 — sulphide              | $\text{NiS}$  | 90.74           |                          |
| 11 — sulphate              | $\text{NiSO}_4$                                     | 154.74          | 3.418                    |
| 12 — —, hydrate            | $\text{NiSO}_4 + 6 \text{H}_2\text{O}$              | 262.84          | 2.031                    |
| 13 — —, hydrate            | $\text{NiSO}_4 + 7 \text{H}_2\text{O}$              | 280.86          | 1.98                     |
| 14 — tetra-carbonyl        | $\text{Ni}(\text{CO})_4$                            | 170.70          | 1.3185/17°               |
| 15 Nitric acid             | $\text{HNO}_3$                                      | 63.02           | 1.54/0°                  |
| 16 — —, hydrate            | $\text{HNO}_3 + 32\% \text{H}_2\text{O}$            |                 | 1.414/15.5°              |
| 17 — oxide                 | $\text{NO}$   | 30.01           | 0.00135                  |
| 18 Nitrogen                | $\text{N}$  | 14.01           | liq. : 0.804/<br>-199.5° |
| 19 — iodide                | $\text{N}_2\text{H}_5\text{I}$                      | 411.80          | 3.5                      |
| 20 — pentasulphide         | $\text{N}_2\text{S}_5$                              | 188.32          | 1.961/18°                |
| 21 — pentoxide             | $\text{N}_2\text{O}_5$                              | 108.02          | 1.64/18°                 |
| 22 — sulphide              | $\text{N}_4\text{S}_4$                              | 184.28          | 2.22                     |
| 23 — tetroxide             | $\text{N}_2\text{O}_4$                              | 92.02           | liq. : 1.4903/0          |
| 24 — trichloride           | $\text{NCl}_3$                                      | 120.39          | 1.65                     |
| 25 — trioxide              | $\text{N}_2\text{O}_3$                              | 76.02           | liq. : 1.447/ - 2°       |
| 26 Nitrous oxide           | $\text{N}_2\text{O}$                                | 44.02           | liq. : 1.226/<br>- 89.4° |
| 27 Nitrosyl bromide        | $\text{NOBr}$                                       | 109.93          | < $\text{H}_2\text{O}$   |
| 28 — chloride              | $\text{NOCl}$                                       | 65.47           | 1.425/ - 15°             |
| 29 Nitrosylsulphuric acid  | $\text{NO} \cdot \text{SO}_2 \cdot \text{OH}$       | 111.08          |                          |
| 30 — anhydride             | $(\text{SO}_2 \cdot \text{NO}_2)_2\text{O}$         | 236.14          |                          |
| 31 Nitroxyl chloride       | $\text{NO}_2\text{Cl}$                              | 81.47           | 1.316/14°                |
| 32 Osmium                  | $\text{Os}$   | 190.9           | 22.479                   |
| 33 — monoxide              | $\text{OsO}$  | 206.9           |                          |

| Crystalline<br>form and<br>colour | Solubility* in                       |  | Alcohol,<br>acids<br>or alkalies | M.P.<br>°C. | B.P.<br>°C.  |    |
|-----------------------------------|--------------------------------------|--|----------------------------------|-------------|--------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) |                                  |             |              |    |
| III.                              | s.                                   | s.                                     | s. alc.                          |             |              | 1  |
| Bl.                               | i.                                   | i.                                     | s. ac., $\text{NH}_4\text{OH}$   |             |              | 2  |
| V. G.                             | 50                                   | v.s.                                   | s. alc.                          | 56.7        | 136.7        | 3  |
| G.                                | i.                                   | i.                                     | s. ac.                           |             |              | 4  |
|                                   | i.                                   | i.                                     | s. KCN                           |             |              | 5  |
| G.                                | i.                                   | i.                                     | s. ac., $\text{NH}_4\text{OH}$   |             |              | 6  |
| I. Gr. Bl. G                      | i.                                   |  | s. $\text{NH}_4\text{OH}$        |             |              | 7  |
| G. Bl.                            | i.                                   | i.                                     | i. $\text{HCl}$                  |             |              | 8  |
| Bl.                               |                                      |  | s. $\text{HCl}$ reduc.           | d.          |              | 9  |
| III., Bl. G                       | i.                                   |  | s. s. ac., s. KHS                |             |              | 10 |
| Y.                                | 36.5                                 | 61.9 (70°)                             | i. alc.                          |             |              | 11 |
| II. Bl., V. G                     | s.                                   | s.                                     | s. $\text{NH}_4\text{OH}$        | 6 aq 280    |              | 12 |
| IV. G.                            | 36.5                                 | 83.7                                   |                                  | 6 aq 103    |              | 13 |
| O.                                | 0.018 (9.8°)                         |  | s. alc.                          | -25         | 43.2         | 14 |
|                                   | m.                                   | m.                                     | d. alc.                          | -40.3       | 86           | 15 |
|                                   | m.                                   | m.                                     | d. alc.                          | liq.        | 120.5        | 16 |
|                                   | 1:20 vol.                            | v.s.s.                                 | s. $\text{FeSO}_4$ soln.         | < -167      | -153         | 17 |
|                                   | 0.0235:                              |  |                                  | -210        | -199.5       | 18 |
|                                   | 1 vol. (4°)                          |  |                                  |             |              |    |
| dark R.                           | s.s.                                 |  |                                  | expl.       |              | 19 |
|                                   | d.                                   |  |                                  |             |              |    |
| R.                                | i.                                   |  | s. s. $\text{OS}_2$ , alc.       | 10-11       | d.           | 20 |
| IV.                               | s.                                   | s.                                     | d. alc.                          | 30          | d. 47        | 21 |
| R. prism.                         | i.                                   |  | s. $\text{OS}_2$                 | subl. 135   | d. > 178     | 22 |
|                                   | d.                                   |  |                                  | -10.1       | 26           | 23 |
| IV.                               | i. d.                                |  | s. org. solv.                    | liq.        | expl. 95     | 24 |
| R.                                | s.                                   | d.                                     | d.                               | -111        | d. 3.5       | 25 |
|                                   | 0.7778:                              | s.s.                                   | s. s. alc.                       | -103.7      | -89.4/741mm. | 26 |
|                                   | 1 vol.                               |  |                                  |             |              |    |
| Br.                               | d.                                   |  |                                  | liq.        | d. -2        | 27 |
| Y.                                | d.                                   |  |                                  | -60         | -5.6/751mm.  | 28 |
| IV.                               | d.                                   |  | s. $\text{H}_2\text{SO}_4$       | 73          |              | 29 |
| II.                               | d.                                   |  | s. $\text{H}_2\text{SO}_4$       | 217         | 360          | 30 |
| Y.                                | d.                                   |  |                                  | liq.        |              | 31 |
| I. W. Viol.                       | i.                                   |  |                                  | 2700        |              | 32 |
| Gr. Bl.                           | i.                                   | i.                                     | i. ac.                           |             |              | 33 |

| Name.  | Formula.   | Density.        |                          |
|--|--|-----------------|--------------------------|
|  |  | Formula Weight. | Water=1<br>D:Air=1       |
| 1 Osmium tetrachloride                       | $\text{OsCl}_4$  | 332.7           |                          |
| 2 — tetroxide                                | $\text{OsO}_4$   | 254.4           |                          |
| 3 Oxygen                                     | O  | 16.00           | liq : 1.118/<br>- 182.5° |
| 4 Ozone                                      | $\text{O}_3$   | 48.00           |                          |
| 5 Palladious bromide                         | $\text{PdBr}_2$  | 266.5           |                          |
| 6 — chloride                                 | $\text{PdCl}_2 + 2 \text{H}_2\text{O}$                               | 213.7           |                          |
| 7 — cyanide                                  | $\text{PdC}_2\text{N}_2$   | 158.7           |                          |
| 8 — iodide                                   | $\text{PdI}_2$   | 360.5           |                          |
| 9 — sulphate                                 | $\text{PdSO}_4 + 2 \text{H}_2\text{O}$                               | 238.8           |                          |
| 10 Palladium                                 | Pd   | 106.7           | 11.4/22.5°               |
| 11 — hydrogen                                |  |                 | 11.06                    |
| 12 — subsulphide                             | $\text{Pd}_2\text{S}$  | 245.5           | 7.36/15°                 |
| 13 Perchloric acid                           | $\text{HClO}_4$  | 100.47          | 1.76/22°                 |
| 14 — —, hydrate                              | $\text{HClO}_4 + \text{H}_2\text{O}$                                 | 118.49          | 1.811                    |
| 15 — —, dihydrate                            | $\text{HClO}_4 + 2 \text{H}_2\text{O}$                               | 136.51          | 1.7                      |
| 16 Per-iodic acid                            | $\text{HIO}_4$   | 227.96          |                          |
| 17 Persulphuric acid                         | $\text{H}_2\text{S}_2\text{O}_8$                                     | 194.14          |                          |
| 18 Phosgene, <i>see</i><br>Carbonyl chloride |  |                 |                          |
| 19 Phospham                                  | $\text{PHN}_3$   | 60.07           |                          |
| 20 Phosphomolybdic acid                      | $\text{H}_3\text{PO}_4 \cdot 12\text{MoO}_3 + 12 \text{H}_2\text{O}$ | 2042.3          |                          |
| 21 Phosphonium bromide                       | $\text{PH}_4\text{Br}$   | 114.99          |                          |
| 22 — chloride                                | $\text{PH}_4\text{Cl}$   | 70.53           |                          |
| 23 — iodide                                  | $\text{PH}_4\text{I}$  | 161.99          |                          |
| 24 Phosphoretted<br>hydrogen, gas.           | $\text{PH}_3$  | 34.06           |                          |
| 25 — —, liq.                                 | $\text{P}_2\text{H}_4$   | 66.11           | 1.016                    |
| 26 — —, solid                                | $\text{P}_4\text{H}_2$   | 126.18          |                          |
| 27 Phosphoric acid, meta                     | $\text{HPO}_3$   | 80.05           |                          |
| 28 — —, ortho                                | $\text{H}_3\text{PO}_4$  | 98.06           | liq. : 1.88              |
| 29 — —, pyro                                 | $\text{H}_4\text{P}_2\text{O}_7$                                     | 178.11          |                          |
| 30 Phosphorous acid                          | $\text{H}_3\text{PO}_3$  | 82.06           | 1.65/21°                 |
| 31 Phosphorus, white                         | P  | 31.04           | 1.836/0°                 |
| 32 —, red                                    | P  | 31.04           | 2.16                     |



| Crystalline<br>form and<br>colour | Solubility*in                        |  | Alcohol,<br>acids<br>or alkalies | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------------------|--------------------------------------|--|----------------------------------|-------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) |                                  |             |             |    |
| R.                                | v.s.                                 | s.                                     | s. HCl, alc.                     |             |             | 1  |
| V. C.                             | s.                                   | s.                                     | alk., alc.                       | 20          | 100         | 2  |
|                                   | 4.89                                 | i.                                     | alc. 28.4                        | - 230       | - 182.5     | 3  |
|                                   | vol./0°                              |  | vol./0°                          |             |             |    |
|                                   | v.s.s.                               |  | s. eth. oils                     | d. 270      | - 119       | 4  |
| Br.                               | i.                                   | i.                                     | s. HBr                           |             |             | 5  |
| Bl., R.                           | s.                                   | s.                                     | s. HCl                           | R.H. & d.   |             | 6  |
| Y.                                | i.                                   | i.                                     | s. KCN, NH <sub>4</sub> OH       | d.          |             | 7  |
| Bl.                               | i.                                   | i.                                     | s. alc., KI                      | d. 100      |             | 8  |
| R.                                | v.s.                                 | v.s.                                   |                                  |             |             | 9  |
| W.Gr.                             |                                      |  | s. HCl, HNO <sub>3</sub>         | 1549        | 2300        | 10 |
|                                   |                                      |  |                                  | d.          |             | 11 |
| Gr.                               | i.                                   | i.                                     | i. ac.                           | R.H.        |             | 12 |
|                                   | s.                                   | s.                                     |                                  | - 35 liq.   | 39/56 mm.   | 13 |
| Cryst.                            | s.                                   | s.                                     |                                  | 50          | expl. 110   | 14 |
|                                   | m.                                   | s.                                     |                                  | liq.        | 203         | 15 |
|                                   | s.                                   |  |                                  | d. 133      |             | 16 |
|                                   | s.                                   | d.                                     |                                  |             |             | 17 |
|                                   |                                      |  |                                  |             |             | 18 |
| W. pdr.                           | .                                    | i.                                     | i.                               | infusible   |             | 19 |
| V. Y.                             | s.                                   |  |                                  | aq 104      |             | 20 |
| I. O.                             | d.                                   |  | d.                               |             | 30          | 21 |
| I.                                | d.                                   |  |                                  | 26          | subl.       | 22 |
| II. O.                            | d.                                   |  | d.                               | subl.       | 80          | 23 |
|                                   | s.s.                                 | i.                                     |                                  | - 133.5     | - 85        | 24 |
| O.                                | i.                                   | i.                                     |                                  | < - 10      | 57/795 mm   | 25 |
| Y.                                | i.                                   | i.                                     |                                  | unites 160  | d.          | 26 |
| Glassy                            | s.                                   | s.                                     |                                  |             | Volatile    | 27 |
|                                   |                                      |  |                                  |             | bright R.H. |    |
| IV.                               | deliq.                               | v.s.                                   | s. alc                           | 38.6        | aq 160 and  | 28 |
|                                   |                                      |  |                                  |             | 290         |    |
|                                   | v.s.                                 | v.s.                                   | v.s.                             | 61          |             | 29 |
| O., cryst.                        | v.s.                                 | v.s.                                   |                                  | 70.1        | d. 200      | 30 |
| I. O.                             | i.                                   | i.                                     | s. CS <sub>2</sub>               | 44.2        | 290         | 31 |
| Am., R.Br.                        | i.                                   | i.                                     | i. CS <sub>2</sub>               |             |             | 32 |

| Name.                       | Formula.                               | Density.        |                                      |
|-----------------------------|--|-----------------|--------------------------------------|
|                             |  | Formula Weight. | Water=1<br>D: Air=1                  |
| 1 Phosphorus, black         | P                                      | 31.04           | 2.34                                 |
| 2 — di-iodide               | P <sub>2</sub> I <sub>4</sub>          | 569.76          |                                      |
| 3 — oxybromide              | POBr <sub>2</sub>                      | 286.80          | 2.822                                |
| 4 — oxychloride             | POCl <sub>3</sub>                      | 153.42          | D : 5.334/151°;<br>1.69/5°           |
| 5 — oxyfluoride             | POF <sub>3</sub>                       | 104.04          | 3.7                                  |
| 6 — pentabromide            | PBr <sub>5</sub>                       | 430.64          |                                      |
| 7 — pentachloride           | PCl <sub>5</sub>                       | 208.34          | D : 3.60/296°                        |
| 8 — pentafluoride           | PF <sub>5</sub>                        | 126.04          |                                      |
| 9 — pentaselenide           | P <sub>2</sub> Se <sub>5</sub>         | 458.08          |                                      |
| 10 — pentasulphide          | P <sub>2</sub> S <sub>5</sub>          | 222.38          |                                      |
| 11 — pentoxide              | P <sub>2</sub> O <sub>5</sub>          | 142.08          | 2.387                                |
| 12 — tribromide             | PBr <sub>3</sub>                       | 270.80          | 2.925/0°                             |
| 13 — trichloride            | PCl <sub>3</sub>                       | 137.42          | 1.6129/0°                            |
| 14 — tri-iodide             | PI <sub>3</sub>                        | 411.80          |                                      |
| 15 — trioxide               | P <sub>2</sub> O <sub>3</sub>          | 110.08          | liq : 1.936/25°;<br>solid : 2.135/21 |
| 16 Phosphoryl<br>imidoamide | PO(NH)(NH <sub>2</sub> )               | 78.08           |                                      |
| 17 — nitride                | PON                                    | 61.05           |                                      |
| 18 — triamide               | PO(NH <sub>2</sub> ) <sub>3</sub>      | 95.12           |                                      |
| 19 Platinic bromide         | PtBr <sub>4</sub>                      | 514.9           |                                      |
| 20 — chloride               | PtCl <sub>4</sub> + 5 H <sub>2</sub> O | 427.1           |                                      |
| 21 — hydroxide              | Pt(OH) <sub>4</sub>                    | 263.2           |                                      |
| 22 Platinous bromide        | PtBr <sub>2</sub>                      | 355.0           |                                      |
| 23 — chloride               | PtCl <sub>2</sub>                      | 266.1           | 5.87                                 |
| 24 — cyanide                | PtC <sub>2</sub> N <sub>2</sub>        | 247.2           |                                      |
| 25 — hydroxide              | Pt(OH) <sub>2</sub>                    | 229.2           |                                      |
| 26 — iodide                 | PtI <sub>2</sub>                       | 449.0           |                                      |
| 27 Platinum                 | Pt                                     | 195.2           | 21.4                                 |
| 28 — dioxide                | PtO <sub>2</sub>                       | 227.2           |                                      |
| 29 — disulphide             | PtS <sub>2</sub>                       | 259.3           | 7.224                                |
| 30 — monosulphide           | PtS                                    | 227.3           |                                      |
| 31 — monoxide               | PtO                                    | 211.2           |                                      |
| 32 Potassamide              | KNH <sub>2</sub>                       | 55.12           |                                      |

| Crystalline<br>form and<br>colour | Solubility*in                        |  | Alcohol,<br>acids<br>or alkalies                   | M.P.<br>°C.           | B.P.<br>°C. |    |
|-----------------------------------|--------------------------------------|--|--|-----------------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) |  |                       |             |    |
| IIIa                              | i.                                   | i                                      | i. CS <sub>2</sub>                                 |                       |             | 1  |
| Y.R. cryst.                       | d.                                   |  | s. CS <sub>2</sub>                                 | 110                   |             | 2  |
| Cryst.                            | d.                                   |  | s. H <sub>2</sub> SO <sub>4</sub>                  | 55—56                 | 195         | 3  |
|                                   | d.                                   |  | d.   | -1.5                  | 110         | 4  |
| O.                                | d.                                   |  |  | -68                   | -40         | 5  |
| Y. cryst.                         | d.                                   |  | d.   | <100                  | d. 100      | 6  |
| II, W. cryst                      | d.                                   |  | i. CS <sub>2</sub>                                 | 148 under<br>pressure | subl. 162   | 7  |
|                                   | d.                                   |  |  | -83                   | -75         | 8  |
| Bl.                               | d.                                   |  | i. CS <sub>2</sub> , s. CCl <sub>4</sub>           | d.                    |             | 9  |
| Y. cryst.                         | d.                                   |  | s. CS <sub>2</sub>                                 | 275                   | 530         | 10 |
| Am. W.                            | deliq.                               | d.                                     |  | subl R.H.             |             | 11 |
| O.                                | d.                                   |  | d.   | -41.5                 | 175         | 12 |
| O.                                | d.                                   |  | s. CS <sub>2</sub>                                 | -112                  | 76          | 13 |
| R. cryst.                         | d.                                   |  | s. CS <sub>2</sub>                                 | 55                    | d.          | 14 |
| Am., W.                           | d.                                   |  | s. CS <sub>2</sub> , C <sub>6</sub> H <sub>6</sub> | 22.5                  | 173.1       | 15 |
| Am. W.                            | i.                                   | d.                                     |  | d.                    |             | 16 |
| Am. W.                            | i.                                   | i.                                     |  | R.H.                  |             | 17 |
| Am. W.                            | i.                                   | i.                                     | s. alc., i. ac.                                    | d.                    |             | 18 |
| Br.                               | s.s.                                 | s.s.                                   | s. alc.  |                       |             | 19 |
| V. R.                             | s.                                   | v.s.                                   | s. alc.  | d.                    |             | 20 |
| Br.                               |                                      |  | s. ac., KOH  |                       |             | 21 |
| G.                                | i.                                   | i.                                     | s. HBr   |                       | d. 200      | 22 |
| Gr.G.                             | i.                                   | i.                                     | s. HCl   | d.                    |             | 23 |
| Y.Br.                             | i.                                   | i.                                     | i. alc.  |                       |             | 24 |
| Bl.                               |                                      |  | s. HCl   |                       |             | 25 |
| Bl.                               | i.                                   |  | s. ac., KOH  | d. 350                |             | 26 |
|                                   | i.                                   |  | s. HCl+HNO <sub>3</sub>                            | 1755                  |             | 27 |
| Bl.                               |                                      |  |  |                       |             | 28 |
| Gr.Bl.                            | i.                                   |  | s. HCl, HNO <sub>3</sub>                           | d.                    |             | 29 |
| Bl.                               | i.                                   |  | ac.  |                       |             | 30 |
| Gr.                               |                                      |  |  | d.                    |             | 31 |
| Y.Gr.                             | d.                                   |  |  | 270—272               | subl. 400   | 32 |

| Name.                        | Formula.                               | Density.        |                              |
|------------------------------|--|-----------------|------------------------------|
|                              |  | Formula Weight. | Water=1<br>D : Air=1         |
| 1 Potassium                  | K                                      | 39.10           | D : 3.1/1040°;<br>0.8650/15° |
| 2 — aluminate                | $K_2AlO_4$                             | 196.4           |                              |
| 3 — antimonate               | $K_3SbO_3$                             | 207.3           |                              |
| 4 — arsenate                 | $K_3AsO_4$                             | 256.26          |                              |
| 5 — —                        | $K_3HAsO_3$                            | 202.17          |                              |
| 6 — aurate                   | $AuO \cdot OK + 3H_2O$                 | 322.4           |                              |
| 7 — aurichloride             | $AuCl \cdot KCl + 2H_2O$               | 414.2           |                              |
| 8 — auricyanide              | $AuC_3N_3 \cdot KCN + \frac{1}{2}H_2O$ | 358.4           |                              |
| 9 — aurocyanide              | $AuCN \cdot KCN$                       | 288.3           |                              |
| 10 — bicarbonate             | $KHCO_3$                               | 100.11          | 2.25                         |
| 11 — bisulphate              | $KHSO_4$                               | 136.17          | 2.163                        |
| 12 — bisulphite              | $KHSO_3$                               | 120.17          |                              |
| 13 — borofluoride            | $KBF_4$                                | 126.0           | 2.51/20°                     |
| 14 — bromate                 | $KBrO_3$                               | 167.02          | 3.271/17.5°                  |
| 15 — bromide                 | KBr                                    | 119.02          | 2.681/15°                    |
| 16 — carbonate               | $K_2CO_3$                              | 138.2           | 2.267                        |
| 17 — carbonyl                | $K_2C_2O_6$                            | 402.63          |                              |
| 18 — chlorate                | $KClO_3$                               | 122.56          | 2.34/17°                     |
| 19 — chloride                | KCl                                    | 74.56           | 1.995/15°                    |
| 20 — chromate                | $K_2CrO_4$                             | 194.2           | 2.7                          |
| 21 — chromicyanide           | $K_3Cr(CN)_6$                          | 325.4           |                              |
| 22 — cobalticyanide          | $K_3Co(CN)_6$                          | 332.36          | 1.906                        |
| 23 — cobaltinitrite          | $K_3Co(NO_2)_6$                        | 452.33          |                              |
| 24 — cobalt sulphate         | $K_2SO_4 \cdot CoSO_4 + 6H_2O$         | 437.39          | 2.154/40°                    |
| 25 — cyanate                 | $KCN O$                                | 81.12           | 2.048                        |
| 26 — cyanide                 | KCN                                    | 65.12           | 1.52/16°                     |
| 27 — dichromate              | $K_2Cr_2O_7$                           | 294.2           | 2.69/4°                      |
| 28 — dihydrogen<br>phosphate | $KH_2PO_4$                             | 136.16          | 2.3                          |
| 29 — disulphate              | $K_2S_2O_7$                            | 254.32          | 2.27                         |
| 30 — dithionate              | $K_2S_2O_6$                            | 238.32          | 2.28                         |
| 31 — ferric sulphate         | $K_2SO_4 \cdot Fe_2(SO_4)_3 + 24H_2O$  | 1006.60         |                              |
| 32 — ferricyanide            | $K_3Fe_2(CN)_{12}$                     | 658.46          | 1.82/17°                     |
| 33 — ferrocyanide            | $K_4Fe_2(CN)_{12} + 3H_2O$             | 422.38          | 1.85/17°                     |

| Crystalline form and colour | Solubility*in                  |                                  |                            | M P.<br>°C.             | B.P.<br>°C. |    |
|-----------------------------|--------------------------------|----------------------------------|----------------------------|-------------------------|-------------|----|
|                             | 100 parts water at 15°C (60°F) | 100 parts water at 100°C (212°F) | Alcohol, acids or alkalies |                         |             |    |
| II., W.                     | d.                             |                                  | d. alc.                    | 62.5                    | 720         | 1  |
|                             | s.                             |                                  |                            |                         |             | 2  |
|                             | i.                             | d.                               |                            |                         |             | 3  |
| Needles                     | 18.87                          | v.s.                             | s. alc.                    |                         |             | 4  |
|                             | v.s.                           | v.s.                             |                            |                         |             | 5  |
| Y. needles                  | s.                             | v.s.                             |                            |                         |             | 6  |
| IV. plates                  | s.                             | s.                               |                            |                         |             | 7  |
| C.                          | s.                             | s.                               | i. alc.                    |                         |             | 8  |
| IV. C.                      | 14.3                           | 200                              |                            |                         |             | 9  |
| V.                          | 25.07                          | 83.0                             | alc. h. 0.083              | d.                      |             | 10 |
| IV, V.                      | v.s.                           | v.s.                             |                            | 197                     | d.          | 11 |
| W. needles                  | s.                             | s.                               | i. alc.                    | d. 190                  |             | 12 |
| W. cryst.                   | s.                             |                                  | s. alc.                    |                         |             | 13 |
| IIIa                        | 6.667                          | 49.75                            | s.s. alc.                  | d. 703                  |             | 14 |
| I.                          | 63.0                           | 102.0                            | alc. 0.5                   | 745                     | sub. W.H.   | 15 |
| V.                          | 109                            | 156                              | i. alc.                    | 880                     | d. 810      | 16 |
| Gr.R.                       | expl.                          |                                  | d. alc.                    | expl.                   |             | 17 |
| V.                          | 6.0                            | 56.5                             | alc. 0.833                 | 370                     | d. 400      | 18 |
| I.                          | 33.4                           | 56.6                             | alc. 0.5                   | 770                     | subl W.H.   | 19 |
| IV., Y.                     | 61.9                           | 79.1                             | i. alc.                    | R.H.                    |             | 20 |
| V., Y.                      | i.                             | i.                               | s. ac., alk.               | 3 aq in vac<br>4 aq 100 |             | 21 |
|                             | v.s.                           | v.s.                             | i. alc.                    | d.                      |             | 22 |
| Y. prism.                   | s.s.                           | s.s.                             | i. alc.                    |                         |             | 23 |
| V. plates                   | 32.5                           | v.s.                             |                            |                         |             | 24 |
| B. needles                  | s.                             |                                  | s. alc.                    |                         |             | 25 |
| I.                          | v.s.                           |                                  | v.s.s. alc.                | R.H.                    | R.H.        | 26 |
| VI., R.                     | 9.9                            | 94.1                             | i. alc.                    | 400                     | d           | 27 |
| II.                         | v.s.                           |                                  | i. alc.                    | d.                      |             | 28 |
| Needles                     | s.                             | d.                               |                            | 210                     | d           | 29 |
| III. C.                     | 6                              | 75                               | i. alc.                    | d.                      |             | 30 |
| I. Viol.                    | 20                             | v.s.                             |                            |                         |             | 31 |
| V. R.                       | 40                             | 80                               | i. alc                     | d.                      |             | 32 |
| V. Y.                       | 28                             | 100                              | i. alc                     | 3 aq 60—80              |             | 33 |

| Name.                   | Formula.   | Density.        |                          |
|-------------------------|--|-----------------|--------------------------|
|                         |  | Formula Weight. | Water=1<br>D:Air=1       |
| 1 Potassium fluoride    | $\text{KF} + 2 \text{H}_2\text{O}$   | 94.1            | 2.454                    |
| 2 — hydride             | $\text{KH}$  | 40.11           |                          |
| 3 — hydrogen phosphate  | $\text{K}_2\text{HPO}_4$   | 174.25          |                          |
| 4 — — sulphide          | $\text{KHS}$   | 72.17           |                          |
| 5 — hydroxide           | $\text{KOH}$   | 56.11           | 2.044                    |
| 6 — hypochlorite        | $\text{KClO}$  | 90.56           |                          |
| 7 — hypophosphite       | $\text{KH}_2\text{PO}_2$   | 104.16          |                          |
| 8 — iodate              | $\text{KIO}_3$   | 214.02          | 3.97/18°                 |
| 9 — iodide              | $\text{KI}$  | 166.02          | D:5.5/1320°;<br>3.04/24° |
| 10 — iodotetrachloride  | $\text{KIOCl}_4$   | 307.86          |                          |
| 11 — magnesium chloride | $\text{KCl} \cdot \text{MgCl}_2 + 6 \text{H}_2\text{O}$                          | 277.90          | 1.618                    |
| 12 — manganate          | $\text{K}_2\text{MnO}_4$   | 197.13          |                          |
| 13 — manganic sulphate  | $\text{K}_2\text{SO}_4 \cdot \text{Mn}_2(\text{SO}_4)_3 + 24 \text{H}_2\text{O}$ | 1004.78         |                          |
| 14 — manganicyanide     | $\text{K}_2\text{Mn}_2(\text{CN})_{12}$  | 656.64          |                          |
| 15 — mangonocyanide     | $\text{K}_8\text{Mn}_2(\text{CN})_{12} + 6 \text{H}_2\text{O}$                   | 842.94          |                          |
| 16 — metabisulphite     | $\text{K}_2\text{S}_2\text{O}_5$   | 222.32          |                          |
| 17 — molybdate          | $\text{K}_2\text{MoO}_4$   | 238.2           |                          |
| 18 — nickel sulphate    | $\text{K}_2\text{SO}_4 \cdot \text{NiSO}_4 + 6 \text{H}_2\text{O}$               | 437.10          | 2.124                    |
| 19 — nitrate            | $\text{KNO}_3$   | 101.11          | 2.087/15°                |
| 20 — nitrite            | $\text{KNO}_2$   | 85.11           |                          |
| 21 — oxide              | $\text{K}_2\text{O}$   | 94.20           | 2.656                    |
| 22 — palladichloride    | $\text{K}_2\text{PdCl}_6$  | 397.7           | 2.8                      |
| 23 — palladiochloride   | $\text{K}_2\text{PdCl}_4$  | 326.7           | 2.738                    |
| 24 — pentasulphide      | $\text{K}_2\text{S}_5$   | 238.50          |                          |
| 25 — perborate          | $\text{KBO}_3$   | 98.0            |                          |
| 26 — perchlorate        | $\text{KClO}_4$  | 138.56          | 2.54                     |
| 27 — periodate          | $\text{KIO}_4$   | 230.02          |                          |
| 28 — permanganate       | $\text{KMnO}_4$  | 158.03          | 2.70/10°                 |
| 29 — peroxide           | $\text{K}_2\text{O}_2$   | 142.20          |                          |
| 30 — persulphate        | $\text{K}_2\text{S}_2\text{O}_8$   | 270.32          |                          |
| 31 — phosphate, meta    | $\text{KPO}_3$   | 118.14          | 2.26                     |
| 32 — —, ortho           | $\text{K}_3\text{PO}_4$  | 212.34          |                          |
| 33 — —, pyro            | $\text{K}_2\text{P}_2\text{O}_7 + 3 \text{H}_2\text{O}$                          | 306.93          | 2.33                     |
| 34 — platinibromide     | $\text{K}_2\text{PtBr}_6$  | 752.9           | 4.541                    |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       | Alcohol,<br>acids<br>or alkalies | M.P.<br>°C.            | B.P.<br>°C. |    |
|-----------------------------------|-------------------------------------|---------------------------------------|----------------------------------|------------------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) |                                  |                        |             |    |
| I.                                | deliq.                              | v.s.                                  | s.s. alc.                        | an. 885                |             | 1  |
| W. needles                        | d.                                  |                                       | reacts $C_2H_2$                  | burns in F<br>Cl and O |             | 2  |
|                                   | deliq.                              | v.s.                                  | v.s. alc.                        | d.                     |             | 3  |
| IIIa, C.                          | s.                                  | s.                                    | s. alc.                          | 455                    |             | 4  |
| +2aq., IIIa                       | 200                                 | v.s.                                  | s. alc.                          | R.H.                   | subl. W.H.  | 5  |
| Needles                           | v.s.                                | v.s.                                  |                                  | d.                     |             | 6  |
| III.                              | deliq.                              |                                       |                                  | d.                     |             | 7  |
| I.                                | 7.2                                 | 32                                    | i. alc.                          | 560                    | d.          | 8  |
| I.                                | 140                                 | 209                                   | alc. 2.5                         | 685                    | 723         | 9  |
| V.                                | d.                                  |                                       |                                  | d.                     |             | 10 |
| III., C., R.                      | 64.5<br>(18.8°)                     | d.                                    |                                  | R.H.                   |             | 11 |
| V., G., Bl.                       | s.                                  | d.                                    | s. alk.                          |                        |             | 12 |
| I., Viol.                         | d.                                  |                                       |                                  |                        |             | 13 |
| R.                                | s.                                  |                                       |                                  |                        |             | 14 |
| II. B.                            | s.                                  |                                       |                                  |                        |             | 15 |
| V. plates                         | s.                                  | d.                                    | s.s. alc.                        | d.                     |             | 16 |
| Micro                             | s.                                  | s.                                    |                                  |                        |             | 17 |
| cryst.                            |                                     |                                       |                                  |                        |             |    |
| V. B.                             | 11.3                                | 45.6 (75°)                            |                                  |                        |             | 18 |
| IV., IIIa                         | 26                                  | 247                                   | i. alc.                          | 334, 340               | d           | 19 |
|                                   | deliq.                              | v.s.                                  | s. alc.                          |                        |             | 20 |
| Gr.                               | v.s.                                | v.s.                                  | v.s. alc.                        | R.H.                   |             | 21 |
| I. R.                             | s.s.                                | d.                                    | i. alc.                          | d.                     |             | 22 |
|                                   | s.                                  | s.                                    | s.s. alc.                        | d.                     |             | 23 |
| Y.Br.                             | v.s.                                | v.s.                                  | v.s. alc.                        | abt. 220°              |             | 24 |
| V.                                | v.s.                                | v.s.                                  |                                  |                        |             | 25 |
| IV.                               | 1.667                               | 18.18                                 | i. alc.                          | 610                    |             | 26 |
| IV.                               | 0.345                               | s.                                    |                                  | 582                    |             | 27 |
| IV. R.Bl.                         | 6.45                                | v.s.                                  | d.                               | d. 240                 |             | 28 |
| Y.                                | d.                                  |                                       | alc. d.                          | R.H.                   | d. W.H.     | 29 |
| VI.                               | 1.76                                | d.                                    |                                  | d.                     |             | 30 |
| Am. W.                            | i.                                  |                                       | s. ac.                           | infusible              |             | 31 |
| IV.                               | s.                                  |                                       | i. alc.                          |                        |             | 32 |
|                                   | s.                                  | v.s.                                  |                                  | aq 100,<br>180, 300    |             | 33 |
| I., R.                            | 2                                   | 10                                    |                                  |                        |             | 34 |

| Name.                          | Formula.                         | Density.        |                    |
|--------------------------------|----------------------------------|-----------------|--------------------|
|                                |                                  | Formula Weight. | Water=1<br>D:Air=1 |
| 1 Potassium<br>platinichloride | $K_2PtCl_6$                      | 486.2           | 3.344              |
| 2 — platinobromide             | $K_2PtBr_4$                      | 593.1           |                    |
| 3 — platinochloride            | $K_2PtCl_4$                      | 415.2           | 3.3/20°            |
| 4 — platinocyanide             | $K_2Pt(ON)_4 + 3H_2O$            | 431.5           | 2.52               |
| 5 — plumbate                   | $K_2PbO_3 + 3H_2O$               | 387.45          |                    |
| 6 — selenate                   | $K_2SeO_4$                       | 221.4           | 3.0657/20°         |
| 7 — silicate                   | $K_2SiO_3$                       | 154.3           |                    |
| 8 — silicofluoride             | $K_2SiF_6$                       | 220.3           | 2.66               |
| 9 — silver cyanide             | $KCN Ag CN$                      | 199.00          |                    |
| 10 — sodium carbonate          | $KNaCO_3 + 6H_2O$                | 230.20          | 1.61               |
| 11 — stannate                  | $K_2SnO_3$                       | 244.9           | 3.197              |
| 12 — sulphate                  | $K_2SO_4$                        | 174.26          | 2.66/20°           |
| 13 — sulphide                  | $K_2S$                           | 110.26          | 2.13               |
| 14 — sulphite                  | $K_2SO_3 + 2H_2O$                | 194.30          |                    |
| 15 — tetraborate               | $K_2B_4O_7 + 5H_2O$              | 324.3           | 1.74               |
| 16 — tetrasilicate             | $K_2Si_4O_9$                     | 334.6           |                    |
| 17 — thiocyanate               | $KCN S$                          | 97.18           | 1.91               |
| 18 — thiosulphate              | $K_2S_2O_3 + H_2O$               | 208.34          |                    |
| 19 — tri-iodide                | $KI_3$                           | 419.86          | 3.498              |
| 20 Red lead                    | $Pb_3O_4$                        | 685.6           | 8.62               |
| 21 Rhodium                     | Rh                               | 102.9           | 12.1               |
| 22 — caesium alum              | $Rh_2(SO_4)_3 Cs_2SO_4 + 24H_2O$ | 1228.1          |                    |
| 23 — chloride                  | $RhCl_3 + 4H_2O$                 | 281.3           |                    |
| 24 — nitrate                   | $Rh_2(NO_3)_6 + 4H_2O$           | 649.9           |                    |
| 25 Rubidium                    | Rb                               | 85.45           | 1.5220/15°         |
| 26 — bromide                   | RbBr                             | 165.37          | 2.78               |
| 27 — carbonate                 | $Rb_2CO_3$                       | 230.90          |                    |
| 28 — chlorate                  | $RbClO_3$                        | 168.91          |                    |
| 29 — chloride                  | RbCl                             | 120.91          | 2.2                |
| 30 — hydride                   | RbH                              | 86.46           | 2.0                |
| 31 — hydroxide                 | RbOH                             | 102.46          |                    |
| 32 — iodide                    | RbI                              | 212.97          | 3.02—3.44          |
| 33 — nitrate                   | $RbNO_3$                         | 147.46          | 3.131              |



| Crystalline<br>form and<br>colour | Solubility*in                       |                                       | Alcohol,<br>acids<br>or alkalies         | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------------------|-------------------------------------|---------------------------------------|--|-------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) |  |             |             |    |
| I., Y.                            | 0.92                                | 5.26                                  |  | d.          |             | 1  |
| IV., Bl.                          | v.s.                                | v.s.                                  |  |             |             | 2  |
| II. R.                            | s.                                  | s.                                    | i. alc.                                  |             |             | 3  |
| IV. Y.                            | deliq.                              | s.                                    | s. H <sub>2</sub> SO <sub>4</sub> , alc. | an. 100     | d. R.H.     | 4  |
| II. C.                            | d.                                  |                                       | s. KOH                                   |             |             | 5  |
| IV.                               | 115 (12°)                           |                                       |  |             |             | 6  |
| Am.                               | s.                                  | s.                                    |  |             |             | 7  |
| I.                                | 0.126                               | 2                                     | i. alc.                                  | d.<br>R.H.  |             | 8  |
| W.                                | 12.5                                | 100                                   | 4 alc.                                   |             |             | 9  |
| V.                                | 20                                  |                                       |  |             | 6 aq 100.   | 10 |
| V. C.                             | s.                                  | s.                                    | s.s. KOH                                 |             |             | 11 |
| IV.                               | 10.3                                | 26.2                                  | i. alc.                                  | 1070        | subl.       | 12 |
| P.                                | v.s.                                | v.s.                                  | s. alc.                                  |             |             | 13 |
| IV.                               | 100                                 | v.s.                                  | i. alc.                                  | d.          |             | 14 |
| III.                              | v.s.                                | v.s.                                  |  | 5 aq R.H.   |             | 15 |
| Am.                               | s.                                  | s.                                    | i. alc.                                  |             |             | 16 |
|                                   | 217 (20°)                           | v.s.                                  | s. alc.                                  | 161         |             | 17 |
| V.                                | v.s.                                | v.s.                                  | i. alc.                                  | aq 200      |             | 18 |
| Prism.                            | d.                                  |                                       | s. KI soln., alc                         | 45          | d.          | 19 |
| R.                                | i.                                  | i.                                    | i. alc.                                  | d. >400     |             | 20 |
| W.                                |                                     |                                       | s.s. ac., s. fus.<br>KHSO <sub>4</sub>   | 1920        |             | 21 |
| Y. oot.                           | s.s.                                |                                       |  | 110—111     |             | 22 |
| R.                                | s.                                  |                                       | s. alc.                                  |             |             | 23 |
| P.                                | s.                                  | s.                                    | i. alc.                                  |             |             | 24 |
| W.                                | d.                                  |                                       |  | 38.5        | R.H.        | 25 |
| W.                                | 98 (5°)                             | 105 (16°)                             |  |             |             | 26 |
| C.                                | deliq.                              | v.s.                                  |  | 837         | d. 740      | 27 |
| W.                                | 3 (5°)                              | 5 (19°)                               |  |             |             | 28 |
| I. C.                             | 82.9 (7°)                           |                                       |  | 710         |             | 29 |
| C. needles                        |                                     |                                       |  | d. 300      |             | 30 |
|                                   |                                     |                                       |  | in vac      |             |    |
| W.                                | 1.18 (25°)                          | 11.76                                 | s. alc.                                  | <R.H.       |             | 31 |
|                                   | 137 (7°)                            | 152 (18°)                             |  | R.H.        |             | 32 |
| III. needle                       | 19.5 (0°)                           | 452                                   | v.s. HNO <sub>3</sub>                    |             |             | 83 |

| Name.                  | Formula.   | Density.        |                                      |
|------------------------|--|-----------------|--------------------------------------|
|                        |  | Formula Weight. | Water=1<br>D:Air=1                   |
| 1 Rubidium perchlorate | RbClO <sub>4</sub>                                   | 184.91          |                                      |
| 2 — platinichloride    | Rb <sub>2</sub> PtCl <sub>6</sub>                    | 578.9           |                                      |
| 3 — sulphate           | Rb <sub>2</sub> SO <sub>4</sub>                      | 266.96          | 3.64                                 |
| 4 Ruthenium tetroxide  | RuO <sub>4</sub>                                     | 165.7           | liq > H <sub>2</sub> SO <sub>4</sub> |
| 5 Selenic acid         | H <sub>2</sub> SeO <sub>4</sub> (+xH <sub>2</sub> O) | 145.2           | 2.95/15°                             |
| 6 Selenious acid       | H <sub>2</sub> SeO <sub>3</sub>                      | 129.2           | 3.01/15.7°                           |
| 7 Selenium, metal.     | Se   | 79.2            | 4.80                                 |
| 8 —, cryst.            | Se   | 79.2            | 4.5                                  |
| 9 —, amorph.           | Se   | 79.2            | D:5.68/1400°;<br>4.26/20°            |
| 10 — dioxide           | SeO <sub>2</sub>                                     | 111.2           | 3.95/15°                             |
| 11 — monobromide       | Se <sub>2</sub> Br <sub>2</sub>                      | 318.2           | 3.604/15°                            |
| 12 — monochloride      | Se <sub>2</sub> Cl <sub>2</sub>                      | 229.3           | 2.91/17°                             |
| 13 — mono-iodide       | Se <sub>2</sub> I <sub>2</sub>                       | 412.2           |                                      |
| 14 — monosulphide      | SeS  | 111.3           | 3.056/0°                             |
| 15 — nitride           | Se <sub>2</sub> N <sub>2</sub>                       | 186.4           |                                      |
| 16 — oxychloride       | SeOCl <sub>2</sub>                                   | 166.1           | 2.44                                 |
| 17 — potassium cyanide | KCN·Se   | 144.3           |                                      |
| 18 — tetrabromide      | SeBr <sub>4</sub>                                    | 398.9           |                                      |
| 19 — tetrachloride     | SeCl <sub>4</sub>                                    | 221.0           |                                      |
| 20 — tetra-iodide      | SeI <sub>4</sub>                                     | 586.9           |                                      |
| 21 Silica              | SiO <sub>2</sub>                                     | 60.1            | Cryst. 2.66;<br>amorph.<br>2.2/16°   |
| 22 Silicio acid (meta) | H <sub>2</sub> SiO <sub>3</sub>                      | 78.1            | 2.324                                |
| 23 Silico-bromoform    | SiHBr <sub>3</sub>                                   | 268.9           | 2.7                                  |
| 24 — chloroform        | SiHCl <sub>3</sub>                                   | 135.5           | 1.344                                |
| 25 — iodoform          | SiHI <sub>3</sub>                                    | 409.9           | 3.4                                  |
| 26 Silicon, cryst.     | Si   | 28.1            | 2.49                                 |
| 27 — carbide           | SiC  | 40.1            | 3.22/15°                             |
| 28 — disulphide        | SiS <sub>2</sub>                                     | 92.2            |                                      |
| 29 — tetrabromide      | SiBr <sub>4</sub>                                    | 347.8           | 2.813/0°                             |
| 30 — tetrachloride     | SiCl <sub>4</sub>                                    | 169.9           | 1.475                                |
| 31 — tetrafluoride     | SiF <sub>4</sub>                                     | 104.1           |                                      |
| 32 — tetrahydride      | SiH <sub>4</sub>                                     | 32.1            |                                      |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       | Alcohol,<br>acids<br>or alkalis                        | M.P.<br>°C. | B.P.<br>°C.  |    |
|-----------------------------------|-------------------------------------|---------------------------------------|--|-------------|--------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) |  |             |              |    |
| IV.                               |                                     | 1 (100°)                              |  |             |              | 1  |
| I. Y.                             | v.s.s.                              |                                       | i. alc.  |             |              | 2  |
| IV. C.                            | 42.4 (10°)                          |                                       |  | W.H.        |              | 3  |
| IV. Y.                            | s. d                                |                                       | s. alc.  | 50          | 100          | 4  |
| III. W.                           | m.                                  | s.                                    |  | 58          | 260          | 5  |
| C. cryst.                         | v.s.                                | v.s.                                  |  | d.          |              | 6  |
| Gr.                               | i.                                  | i.                                    | i. CS <sub>2</sub> , s. H <sub>2</sub> SO <sub>4</sub> | 217         | 690          | 7  |
| V., R. Bl.                        | i.                                  | i.                                    | CS <sub>2</sub> , 1 : 1000                             | 220         |              | 8  |
| R.                                | i.                                  | i.                                    | CS <sub>2</sub> , 1 : 1000                             | 100—250     |              | 9  |
| W. cryst                          | s.                                  | s.                                    |  |             | subl. 260    | 10 |
| P.                                | d.                                  |                                       | alc. d.  | liq.        | d. 225       | 11 |
| Y. Br.                            | d.                                  |                                       |  | liq.        | d. 145       | 12 |
|                                   | d.                                  |                                       |  | 60—70       |              | 13 |
| Y.                                | i.                                  | i.                                    | s. ether, CS <sub>2</sub>                              | 118—119     |              | 14 |
| Am. Y.                            | i.                                  | i.                                    | i. alc., s. CS <sub>2</sub>                            | expl. 200   |              | 15 |
| W.                                | d.                                  |                                       |  | 10          | 179.5        | 16 |
| Needles                           | s.                                  |                                       | ac. d.   | d. 100      |              | 17 |
| Br.                               | d.                                  |                                       | s. HCl, CS <sub>2</sub>                                | 75          | d.           | 18 |
| W.                                | d.                                  |                                       | s. POCl <sub>3</sub>                                   | subl.       | diss. 200    | 19 |
| Gr.                               | d.                                  |                                       |  | 75—80       |              | 20 |
| Am. & cryst                       | i.                                  | i.                                    | i. alc.  | 1780        |              | 21 |
| Am. W.                            | freshly<br>pptd. insol.             |                                       | s. alk.  |             |              | 22 |
| C.                                | d.                                  |                                       |  |             | 115—117      | 23 |
| C.                                | d.                                  |                                       | m. CS <sub>2</sub>                                     | — 1.3       | 34           | 24 |
| R.                                | d.                                  |                                       |  | liq.        | 220          | 25 |
| III. Bl.,<br>Am. Br.              | i.                                  | i.                                    | s. HF + HNO <sub>3</sub>                               | 1420 ± 15   |              | 26 |
| IV. plates                        | i.                                  | i.                                    | i. ac.   |             |              | 27 |
| W. needles                        | d.                                  |                                       | d.   | subl.       |              | 28 |
| C.                                | d.                                  |                                       |  | — 12        | 153.4        | 29 |
| C.                                | d.                                  |                                       |  | — 89        | 57.5         | 30 |
|                                   | d.                                  |                                       |  | — 102       | — 107        | 31 |
|                                   | i.                                  |                                       |  | — 200       | — 11/50 atm. | 32 |

| Name.                  | Formula.                             | Density.        |                            |
|------------------------|--------------------------------------|-----------------|----------------------------|
|                        |                                      | Formula Weight. | Water=1<br>D:Air=1         |
| 1 Silicon tetra-iodide | $\text{SiI}_4$                       | 535.8           |                            |
| 2 — tribromide         | $\text{Si}_2\text{Br}_6$             | 535.7           |                            |
| 3 — trichloride        | $\text{Si}_2\text{Cl}_6$             | 269.0           | 1.58/0°                    |
| 4 — tri-iodide         | $\text{Si}_2\text{I}_6$              | 817.7           |                            |
| 5 Silico-oxalic acid   | $\text{Si}_2\text{O}_2(\text{OH})_2$ | 122.2           |                            |
| 6 Silver               | $\text{Ag}$                          | 107.88          | 10.47                      |
| 7 — arsenate           | $\text{Ag}_3\text{AsO}_4$            | 462.60          |                            |
| 8 — arsenite           | $\text{Ag}_3\text{AsO}_3$            | 446.60          |                            |
| 9 — bromate            | $\text{AgBrO}_3$                     | 235.80          | 5.196/16°                  |
| 10 — bromide           | $\text{AgBr}$                        | 187.80          | 6.47/25°                   |
| 11 — carbonate         | $\text{Ag}_2\text{CO}_3$             | 275.76          | 6.077                      |
| 12 — chlorate          | $\text{AgClO}_3$                     | 191.34          | 4.43                       |
| 13 — chloride          | $\text{AgCl}$                        | 143.34          | 5.501 ppd.;<br>D:5.7/1735° |
| 14 — chromate          | $\text{Ag}_2\text{CrO}_4$            | 331.8           | 5.625                      |
| 15 — cyanide           | $\text{AgCN}$                        | 133.90          | 3.99                       |
| 16 — dichromate        | $\text{Ag}_2\text{Cr}_2\text{O}_7$   | 431.8           | 4.669                      |
| 17 — fluoride          | $\text{AgF} + \text{H}_2\text{O}$    | 144.90          |                            |
| 18 — iodate            | $\text{AgIO}_3$                      | 282.80          | 5.402/17°                  |
| 19 — iodide            | $\text{AgI}$                         | 234.80          | 5.67/14°                   |
| 20 — nitrate           | $\text{AgNO}_3$                      | 169.89          | 4.35/19°                   |
| 21 — nitride           | $\text{AgN}_3$                       | 149.91          |                            |
| 22 — nitrite           | $\text{AgNO}_2$                      | 153.89          |                            |
| 23 — oxide             | $\text{Ag}_2\text{O}$                | 231.76          | 7.52                       |
| 24 — peroxide          | $\text{Ag}_2\text{O}_2$              | 247.76          | 7.44                       |
| 25 — phosphate         | $\text{Ag}_3\text{PO}_4$             | 418.68          | 7.32                       |
| 26 — —, pyro           | $\text{Ag}_4\text{P}_2\text{O}_7$    | 605.60          | 5.306/7.5°                 |
| 27 — sulphate          | $\text{Ag}_2\text{SO}_4$             | 311.82          | 5.41                       |
| 28 — sulphide          | $\text{Ag}_2\text{S}$                | 247.82          | 7.24 nat.                  |

| Crystalline<br>form and<br>colour | Solubility*in                        |  | Alcohol,<br>acids<br>or alkalis   | M.P.<br>°C.                    | B.P.<br>°C. |    |
|-----------------------------------|--------------------------------------|--|---|--------------------------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) |   |                                |             |    |
| I. C.                             | i.                                   | i                                      | s. $\text{CS}_2$  | 120.5                          | 290         | 1  |
| IV. W.                            | d.                                   |  |   |                                | 240         | 2  |
| W.                                | d.                                   |  |   | -1                             | 146         | 3  |
| III. C.                           | d.                                   |  | s. $\text{CS}_2$  | 250 in vac.                    |             | 4  |
| Am. W.                            | i.                                   |  |   | d.                             |             | 5  |
| I. W.                             | i.                                   | i                                      | s. $\text{HNO}_3$   | 960.5                          | W.H.        | 6  |
| R.                                | i.                                   |  | s. $\text{NH}_4\text{OH}$   |                                |             | 7  |
| Y.                                | i.                                   | i                                      | s. $\text{HNO}_3$ ,<br>$\text{NH}_4\text{OH}$                                   | d.                             |             | 8  |
| II.                               | i.                                   | i                                      | s.s. $\text{HNO}_3$<br>s. $\text{NH}_4\text{OH}$                                |                                |             | 9  |
| I. Y.                             | i.                                   | i                                      | s. conc. $\text{NH}_4\text{OH}$   | 427                            | d. 700      | 10 |
| Y. pdr.                           |                                      |  | s. conc. $\text{HBr}$<br>s. ac.   | loses $\text{CO}_2$<br>at 200° |             | 11 |
| II. W.                            | 10                                   |  |   | 230                            | d. 270      | 12 |
| I. W.                             | i.                                   | i                                      | s. $\text{NH}_4\text{OH}$ ,<br>$\text{KCN}$ , $\text{Na}_2\text{S}_2\text{O}_3$ | 460                            |             | 13 |
| R. cryst.                         | 0.0028 (18°)                         |  | s. ac., $\text{NH}_4\text{OH}$ ,<br>$\text{KCN}$                                |                                |             | 14 |
| W. cryst.                         | i.                                   | i                                      | s. $\text{NH}_4\text{OH}$ ,<br>$\text{KCN}$                                     | m. and d.                      |             | 15 |
| VI. R.                            |                                      | d.                                     |   |                                |             | 16 |
| II. C.                            | deliq.                               | v.s.                                   |   | 435                            |             | 17 |
| W. needles                        | s.s.                                 | s.s.                                   | s. $\text{NH}_4\text{OH}$ ,<br>$\text{HNO}_3$                                   | d.                             |             | 18 |
| III. G.                           | i.                                   |  | v.s.s. $\text{NH}_4\text{OH}$<br>s. conc. $\text{KI}$                           | 540                            |             | 19 |
| IV.                               | 190                                  | 1110                                   | alc. h. 1 : 4   | 218                            | d. R.H.     | 20 |
| W.                                | i.                                   |  | s. $\text{NH}_4\text{OH}$   | expl.                          |             | 21 |
| IIIa, W.                          | s.s.                                 | s.                                     | s. $\text{NH}_4\text{OH}$   | d. 150                         | d. R.H.     | 22 |
| Bl.                               | 0.333                                |  | s. $\text{HNO}_3$   | d. 250                         |             | 23 |
| I. Bl.                            | i.                                   |  | s. $\text{HNO}_3$ ,<br>$\text{NH}_4\text{OH}$                                   | d. 110                         |             | 24 |
| Y.                                | i.                                   |  | s. alk., ac.  | R.H.                           |             | 25 |
| W.                                | i.                                   |  |   | 585                            |             | 26 |
| IV.                               | 0.5                                  | 1.45                                   | v.s. $\text{NH}_4\text{OH}$   | 825                            |             | 27 |
| I., Gr. Bl.                       | i.                                   |  | s. $\text{NH}_4\text{OH}$ ,<br>$\text{HNO}_3$                                   | 676                            | d.          | 28 |

| Name.                     | Formula.   | Density.        |                     |
|---------------------------|--|-----------------|---------------------|
|                           |  | Formula Weight. | Water=1<br>D: Air=1 |
| 1 Silver sulphite         | $\text{Ag}_2\text{SO}_3$                                   | 295.82          |                     |
| 2 — thiocyanate           | $\text{AgCNS}$   | 165.96          |                     |
| 3 — thiosulphate          | $\text{Ag}_2\text{S}_2\text{O}_3$                          | 327.90          |                     |
| 4 Sodamide                | $\text{NaNH}_2$  | 39.03           |                     |
| 5 Sodium                  | $\text{Na}$  | 23.00           | 0.732/15°           |
| 6 — aluminate             | $\text{Na}_2\text{AlO}_2$                                  | 164.0           |                     |
| 7 — aluminium chloride    | $2\text{NaCl}, \text{Al}_2\text{Cl}_6$                     | 383.7           |                     |
| 8 — ammonium phosphate    | $\text{NH}_4\text{NaHPO}_4 + 4\text{H}_2\text{O}$          | 209.15          | 1.55                |
| 9 — antimonate            | $2\text{NaSbO}_3 + 7\text{H}_2\text{O}$                    | 508.5           |                     |
| 10 — arsenate             | $\text{Na}_3\text{AsO}_4 + 12\text{H}_2\text{O}$           | 324.06          | 1.7593              |
| 11 — bicarbonate          | $\text{NaHCO}_3$   | 84.01           | 2.22/16°            |
| 12 — bisulphate           | $\text{NaHSO}_4 + \text{H}_2\text{O}$                      | 138.09          | an. 1.8             |
| 13 — bisulphite           | $\text{NaHSO}_3$   | 104.07          | 1.48                |
| 14 — borate               | $\text{Na}_2\text{B}_4\text{O}_7 + 10\text{H}_2\text{O}$   | 381.8           | 1.7156/17°          |
| 15 — bromate              | $\text{NaBrO}_3$   | 150.92          | 3.339/17.5°         |
| 16 — bromide              | $\text{NaBr} (+ 2\text{H}_2\text{O})$                      | 102.92          | 3.08                |
| 17 — carbonate            | $\text{Na}_2\text{CO}_3 + 10\text{H}_2\text{O}$            | 286.16          | 1.45                |
| 18 — —, an.               | $\text{Na}_2\text{CO}_3$                                   | 106.00          | 2.5                 |
| 19 — chlorate             | $\text{NaClO}_3$   | 106.46          | 2.29                |
| 20 — chloride             | $\text{NaCl}$  | 58.46           | 2.174/20°           |
| 21 — chromate             | $\text{Na}_2\text{CrO}_4 + 10\text{H}_2\text{O}$           | 342.2           | 2.71/16°            |
| 22 — cyanide              | $\text{NaCN}$  | 49.01           |                     |
| 23 — dichromate           | $\text{Na}_2\text{Cr}_2\text{O}_7 + 2\text{H}_2\text{O}$   | 298.0           | 2.52/16°            |
| 24 — dihydrogen phosphate | $\text{NaH}_2\text{PO}_4 + \text{H}_2\text{O}$             | 138.08          | 2.04                |
| 25 — ferriocyanide        | $2\text{Na}_3\text{Fe}(\text{CN})_6 + \text{H}_2\text{O}$  | 579.88          |                     |
| 26 — ferrocyanide         | $\text{Na}_4\text{Fe}(\text{CN})_6 + 12\text{H}_2\text{O}$ | 520.18          |                     |
| 27 — fluoride             | $\text{NaF}$   | 42.0            | 2.766               |
| 28 — hydrosulphite        | $\text{Na}_2\text{S}_2\text{O}_4 (+ 2\text{H}_2\text{O})$  | 174.12          |                     |
| 29 — hydride              | $\text{NaH}$   | 24.01           | 0.92                |
| 30 — hydrogen arsenate    | $\text{Na}_2\text{HAsO}_4 + 12\text{H}_2\text{O}$          | 402.21          | 1.67                |
| 31 — — arsenite           | $\text{Na}_2\text{HAsO}_3$                                 | 169.97          | 1.87                |
| 32 — — phosphate          | $\text{Na}_2\text{HPO}_4 + 12\text{H}_2\text{O}$           | 358.29          | 1.525/16°           |
| 33 — — phosphite          | $\text{Na}_2\text{HPO}_3 + 5\text{H}_2\text{O}$            | 216.13          |                     |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       |                                  | M.P.<br>°C.          | B.P.<br>°C. |    |
|-----------------------------------|-------------------------------------|---------------------------------------|----------------------------------|----------------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) | Alcohol,<br>acids<br>or alkalies |                      |             |    |
| W.                                | i.                                  |                                       | s. $\text{NH}_4\text{OH}$        | d. 400               |             | 1  |
| W.                                | i.                                  | i                                     | s. $\text{NH}_4\text{OH}$        | d.                   |             | 2  |
| W.                                | s.s.                                |                                       | s. $\text{NH}_4\text{OH}$        | d.                   |             | 3  |
| Cryst.                            | s.                                  | d.                                    |                                  | 155                  | subl. 400   | 4  |
| II. (?), W.                       | d.                                  |                                       | d.                               | 97.5                 | 742         | 5  |
|                                   | s.                                  | s.                                    |                                  |                      |             | 6  |
| C.                                | deliq.                              |                                       |                                  | 185                  | R.H.        | 7  |
| V. C.                             | 16                                  | 100                                   | i. alo.                          | d.                   |             | 8  |
| W.                                |                                     |                                       |                                  | 2 aq 200<br>an. R.H. |             | 9  |
|                                   | 26.7 (17°)                          |                                       |                                  |                      |             | 10 |
| V.                                | 8                                   | d.                                    | i. alo.                          | d. 270               |             | 11 |
| V., an. VI.                       | v.s.                                | v.s.                                  | i. alo.                          | 300                  |             | 12 |
|                                   | s.                                  | s.                                    | i. alo.                          |                      |             | 13 |
| V. + 5 aq. I                      | 6.2                                 | 201.4                                 | i. alo.                          | R.H.                 |             | 14 |
| I.                                | s.                                  | s.                                    |                                  | 384                  |             | 15 |
| V., an. I.                        | 87                                  | 120                                   | s.s. alo.                        | 733—765              |             | 16 |
| V.                                | 92.5                                | 539.6                                 | i. alo.                          | 5 aq 12.5,<br>34     | 106         | 17 |
| W. pdr.                           | 16.5                                | 45                                    | i. alo.                          | 853                  | d.          | 18 |
| I.                                | 94.2                                | 232.6                                 | s. alo.                          | 248                  | d.          | 19 |
| I.                                | 35                                  | 39.5                                  | i. alo.                          | 792                  | W.H.        | 20 |
| V. Y.                             | s.                                  | s.                                    |                                  | 23                   |             | 21 |
|                                   | s.                                  | v.s.                                  | s.s. alo.                        |                      |             | 22 |
| VI. R.                            | 109                                 | 163                                   |                                  | aq 110; 320          | d. 400      | 23 |
| IV.                               | s.                                  |                                       | i. alo.                          | d. 200               |             | 24 |
| R. prism.                         | 19.0                                | 80.0                                  |                                  |                      |             | 25 |
| V. Y.                             | s.                                  | s.                                    |                                  |                      |             | 26 |
| I. C.                             | 4.78                                |                                       | s.s. alo.                        | 902                  |             | 27 |
| C. cryst.                         | v.s.                                | d.                                    | i. alo.                          | d. R.H.              |             | 28 |
| C. cryst.                         | d.                                  |                                       | s. fused Na                      | d.                   |             | 29 |
|                                   | 28                                  | v.s.                                  | 1.8 alo.                         |                      |             | 30 |
|                                   | v.s.                                | v.s.                                  |                                  |                      |             | 31 |
| V.                                | aq. free<br>5.8                     | 98.8                                  | i. alo.                          | 38                   | 3 aq 160    | 32 |
| IIIa                              | s.                                  | s.                                    |                                  | 53                   |             | 33 |

| Name.                      | Formula.   | Density.        |                        |
|----------------------------|--|-----------------|------------------------|
|                            |  | Formula Weight. | Water=1<br>D:Air=1     |
| 1 Sodium hydrogen sulphide | $\text{NaHS} + 2\text{H}_2\text{O}$                                | 92.10           |                        |
| 2 — hydroxide              | $\text{NaOH}$  | 40.01           | 2.13                   |
| 3 — hypochlorite           | $\text{NaClO}$   | 74.46           |                        |
| 4 — hypophosphite          | $\text{NaH}_2\text{PO}_2 + \text{H}_2\text{O}$                     | 106.08          |                        |
| 5 — iodide                 | $\text{NaI} + 2\text{H}_2\text{O}$                                 | 185.95          | 2.448;<br>an. 3.65/18° |
| 6 — iodate                 | $\text{NaIO}_3 (+5\text{H}_2\text{O})$                             | 197.92          | 4.277                  |
| 7 — manganate              | $\text{Na}_2\text{MnO}_4 + 10\text{H}_2\text{O}$                   | 345.09          |                        |
| 8 — metastannate           | $\text{Na}_2\text{SnO}_5 + 4\text{H}_2\text{O}$                    | 887.6           |                        |
| 9 — molybdate              | $\text{Na}_2\text{MoO}_4 + 2\text{H}_2\text{O}$                    | 242.0           |                        |
| 10 — monoxide              | $\text{Na}_2\text{O}$  | 62.00           | 2.805                  |
| 11 — nitrate               | $\text{NaNO}_3$  | 85.01           | 2.27/20°               |
| 12 — nitrite               | $\text{NaNO}_2$  | 69.01           |                        |
| 13 — nitroprusside         | $\text{Na}_2\text{Fe}(\text{ON})_5\text{NO} + 2\text{H}_2\text{O}$ | 297.96          |                        |
| 14 — perborate             | $\text{NaBO}_3 + 4\text{H}_2\text{O}$                              | 154.0           |                        |
| 15 — perchlorate           | $\text{NaClO}_4$   | 122.46          |                        |
| 16 — permanganate          | $\text{NaMnO}_4$   | 141.93          |                        |
| 17 — peroxide              | $\text{Na}_2\text{O}_2$  | 78.00           | 2.8                    |
| 18 — pentasulphide         | $\text{Na}_2\text{S}_5 (+8\text{H}_2\text{O})$                     | 206.30          |                        |
| 19 — phosphate, ortho      | $\text{Na}_3\text{PO}_4 + 12\text{H}_2\text{O}$                    | 380.28          | 1.62                   |
| 20 — —, meta               | $\text{NaPO}_3$  | 102.04          | 2.476                  |
| 21 — —, pyro               | $\text{Na}_4\text{P}_2\text{O}_7 + 10\text{H}_2\text{O}$           | 446.24          | 1.8                    |
| 22 — phosphide             | $\text{Na}_3\text{P}$  | 100.04          |                        |
| 23 — platinichloride       | $\text{Na}_2\text{PtCl}_6 + 6\text{H}_2\text{O}$                   | 562.1           | 2.499                  |
| 24 — pyroantimonate        | $\text{Na}_2\text{H}_2\text{Sb}_2\text{O}_7 + 6\text{H}_2\text{O}$ | 508.5           |                        |
| 25 — silicate              | $\text{Na}_2\text{SiO}_3$  | 122.1           |                        |
| 26 — silicofluoride        | $\text{Na}_2\text{SiF}_6$  | 188.3           | 2.75                   |
| 27 — stannate              | $\text{Na}_2\text{SnO}_3 + 3\text{H}_2\text{O}$                    | 266.8           |                        |
| 28 — sulphate              | $\text{Na}_2\text{SO}_4 + 10\text{H}_2\text{O}$                    | 322.22          | 1.492/20°              |
| 29 — suphide               | $\text{Na}_2\text{S} + 9\text{H}_2\text{O}$                        | 240.20          | 2.471                  |
| 30 — suphite               | $\text{Na}_2\text{SO}_3 + 7\text{H}_2\text{O}$                     | 252.17          | 1.561                  |
| 31 — tetrasilicate         | $\text{Na}_2\text{Si}_4\text{O}_9$                                 | 302.4           |                        |
| 32 — thioantimonate        | $\text{Na}_3\text{SbS}_4 + 9\text{H}_2\text{O}$                    | 479.58          | 1.806                  |
| 33 — thioarsenate          | $2\text{Na}_3\text{AsS}_4 + 15\text{H}_2\text{O}$                  | 814.74          |                        |
| 34 — thiosulphate          | $\text{Na}_2\text{S}_2\text{O}_3 + 5\text{H}_2\text{O}$            | 248.20          | 1.736/10°              |



| Crystalline<br>form and<br>colour | Solubility*in                        |  | Alcohol,<br>acids<br>or alkalies                                       | M.P.<br>°C.      | B.P.<br>°C. |    |
|-----------------------------------|--------------------------------------|--|--|------------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) |  |                  |             |    |
| Cryst.                            | deliq.                               |  | s. alc.  | d.               |             | 1  |
| Am. W.                            | 105                                  | 335                                    | s. alc.  | 318              | W.H.        | 2  |
| Needles                           | s.                                   | d.                                     |  | d.               |             | 3  |
|                                   | deliq.                               | s.                                     |  | aq in vac.       |             | 4  |
| I.                                | 174                                  | 300                                    | s. alc.  | abt. 650         |             | 5  |
|                                   | 6.8                                  | 33.9                                   | i. alc., s. acetic   | d.               |             | 6  |
| V. G.                             | v.s.                                 | d.                                     |  |                  |             | 7  |
| Cryst. pdr.                       | s.s.                                 |  | i. alc.  |                  |             | 8  |
| IIIa                              | s.                                   | s.                                     |  |                  |             | 9  |
|                                   | d.                                   |  | d. alc.  | R.H.             | subl.       | 10 |
| IIIa                              | 84                                   | 180                                    | 93% alc. 0.93  | 313              |             | 11 |
| IV.                               | 83                                   | v.s.                                   | i. alc.  | 213              |             | 12 |
| R. prism.                         | 40                                   |  |  |                  |             | 13 |
| V. prism.                         | 2.5 (20°)                            | d.                                     | with H <sub>2</sub> SO <sub>4</sub> :<br>H <sub>2</sub> O <sub>2</sub> |                  |             | 14 |
| IIIa. C.                          | deliq.                               | v.s.                                   |  | d.               |             | 15 |
| R.                                | deliq.                               | v.s.                                   |  | d.               |             | 16 |
| Y.W.                              | s. d.                                |  | with H <sub>2</sub> SO <sub>4</sub> :<br>H <sub>2</sub> O <sub>2</sub> | d.               |             | 17 |
|                                   | s.                                   | s.                                     | s.s. alc.  | d.               |             | 18 |
| III                               | 20                                   | s.                                     |  | 73, 11aq100      |             | 19 |
| W.                                | fused i.                             |  |  | 617              |             | 20 |
| V.                                | 8.8                                  | 93.1                                   | i. alc.  |                  | 76.7        | 21 |
| R.                                | yields PH <sub>3</sub>               |  |  | d.               |             | 22 |
| VI. R.                            | v.s.                                 | v.s.                                   | s. alc.  | an. 100          |             | 23 |
|                                   | v.s.s.                               | v.s.s.                                 | v.s.s. alc.  |                  |             | 24 |
| V.+5 aq.                          | s.                                   | s.                                     | i. alc.  | 1007             |             | 25 |
| III. C.                           | 0.6                                  | 2.5                                    |  |                  |             | 26 |
| III.                              | s.                                   | s.s.                                   |  |                  |             | 27 |
| V., an. IV.                       | (+10 aq.)<br>29.9                    | 113 (33°)                              | i alc.   | 7 aq 150,<br>880 |             | 28 |
| II.                               | s.                                   | s.                                     | s. alc.  | d.               |             | 29 |
| V.                                | (+7 aq.) 46                          | 66                                     | i alc.   | 7 aq 150         | d.          | 30 |
| Am. C                             | s.                                   | s.                                     | i. alc.  |                  |             | 31 |
| I. Y.                             | 33                                   |  | i. alc.  | d.               |             | 32 |
|                                   | s.                                   |  |  |                  |             | 33 |
| V.                                | 65                                   | 109 (45°)                              | i. alc.  | 32—48            | d. 220      | 34 |

| Name.                                 | Formula.  | Density.        |                  |
|---------------------------------------|---|-----------------|------------------|
|                                       |   | Formula Weight. | Water=1<br>Air=1 |
| 1 Sodium tungstate                    | $\text{Na}_2\text{WO}_4 + 2\text{H}_2\text{O}$          | 330.0           | 3.3; an. 4.18    |
| 2 Stannic acid<br>or Metastannic acid | $\text{H}_2\text{SnO}_3$ to<br>$\text{H}_4\text{SnO}_4$ |                 |                  |
| 3 Stannic bromide                     | $\text{SnBr}_4$   | 438.4           | 3.340/35°        |
| 4 — chloride                          | $\text{SnCl}_4$   | 260.5           | 2.27/20°         |
| 5 — fluoride                          | $\text{SnF}_4$  | 194.7           | 4.78/19°         |
| 6 — iodide                            | $\text{SnI}_4$  | 626.4           | 4.696/11°        |
| 7 — oxide                             | $\text{SnO}_2$  | 150.7           | 6.6—6.9          |
| 8 — sulphide                          | $\text{SnS}_2$  | 183.8           | 4.6              |
| 9 Stannous bromide                    | $\text{SnBr}_2$   | 278.5           | 5.117/17°        |
| 10 — chloride                         | $\text{SnCl}_2 + 2\text{H}_2\text{O}$                   | 225.7           | 2.71             |
| 11 — iodide                           | $\text{SnI}_2$  | 372.5           |                  |
| 12 — oxide                            | $\text{SnO}$  | 134.7           | 6.3              |
| 13 — sulphide                         | $\text{SnS}$  | 150.8           | 4.973 cryst.     |
| 14 Strontium                          | $\text{Sr}$   | 87.63           | 2.542            |
| 15 — bromate                          | $\text{Sr}(\text{BrO}_3)_2 + \text{H}_2\text{O}$        | 361.49          | 3.773            |
| 16 — bromide                          | $\text{SrBr}_2 (+6\text{H}_2\text{O})$                  | 247.47          | 4.2/24°          |
| 17 — carbonate                        | $\text{SrCO}_3$   | 147.63          |                  |
| 18 — chlorate                         | $\text{Sr}(\text{ClO}_3)_2$                             | 254.55          | 3.62             |
| 19 — chloride                         | $\text{SrCl}_2 + 6\text{H}_2\text{O}$                   | 266.65          | 1.964; an. 3.05  |
| 20 — dithionate                       | $\text{SrS}_2\text{O}_6 + 4\text{H}_2\text{O}$          | 319.81          | 2.373            |
| 21 — fluoride                         | $\text{SrF}_2$  | 125.63          | 4.2—4.24         |
| 22 — hydroxide                        | $\text{Sr}(\text{OH})_2 + 8\text{H}_2\text{O}$          | 265.78          | 1.396            |
| 23 — iodide                           | $\text{SrI}_2$  | 341.47          | 4.415            |
| 24 — nitrate                          | $\text{Sr}(\text{NO}_3)_2$                              | 211.65          | 2.962/4°         |
| 25 — oxide                            | $\text{SrO}$  | 103.63          | 3.6              |
| 26 — peroxide                         | $\text{SrO}_2 + 8\text{H}_2\text{O}$                    | 263.76          |                  |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       |  | M.P.<br>°C. | B.P.<br>°C.         |    |
|-----------------------------------|-------------------------------------|---------------------------------------|--|-------------|---------------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) | Alcohol,<br>acids<br>or alkalis                                    |             |                     |    |
| C. plates                         | (+2 aq.)<br>55.5                    | 125                                   |  | an. 100     |                     | 1  |
| W.                                | i.                                  | stannic<br>meta<br>stannic            | s. HNO <sub>3</sub> , alk.<br>i HNO <sub>3</sub> ,<br>s. alk., HCl | d.          |                     | 2  |
| W.                                | v.s.                                | d.                                    |  | 33          | 201                 | 3  |
|                                   | s., d.<br>excess aq.                |                                       | s. CS <sub>2</sub>   | liq. - 33   | 114.1               | 4  |
| W. cryst.                         | deliq.                              | d.                                    |  | subl.       | 705                 | 5  |
| R. oct.                           | d.                                  |                                       | s. org. sol.   | 143         | 341                 | 6  |
| II., Am. W                        | i.                                  |                                       | s. alk., i. ac.  | 1130        |                     | 7  |
| Y. III.                           | i.                                  |                                       | s. alk.  | d. R.H.     |                     | 8  |
| Y.                                | s.                                  |                                       |  | 215.5       | 619                 | 9  |
| VI.                               | 275                                 | d. with<br>excess aq.                 | s. alc.  | 40, an. 249 | 620                 | 10 |
| Y.R. ndl.                         | s.s.                                |                                       | s. HCl   | 316         |                     | 11 |
| I. Bl.                            | i.                                  |                                       | s. NH <sub>4</sub> Cl  | d. R.H.     |                     | 12 |
| Gr. Bl.                           | i.                                  |                                       | s. HCl   | R.H.        |                     | 13 |
| Y.                                | d.                                  |                                       |  | <800        | abt. 1000           | 14 |
|                                   | (+aq.) 33                           |                                       |  | aq 100      | d. 240              | 15 |
| C. needles                        | 99 (20°)                            | 250 (110°)                            |  | 498-630     |                     | 16 |
| IV.                               | 0.0056                              |                                       | s. CO <sub>2</sub> soln.   | d. 1160     | d. R.H.             | 17 |
| IV.                               | s.                                  | s.                                    | s.s.   | 290 and d.  |                     | 18 |
| III.                              | 51.0                                | 101.9                                 | alc. 4.6   | an. 854     | 4 aq 60<br>6 aq 100 | 19 |
| III. plates                       | (+ aq.) 20                          | 60                                    | i. alc.  | 4 aq 78     |                     | 20 |
| I.                                | s.                                  | s.                                    |  |             |                     | 21 |
| II.                               | (+8 aq.) 1.9                        | 41                                    |  | 8 aq 100    |                     | 22 |
| Plates                            | 179 (20°)                           | 370                                   |  | 402         |                     | 23 |
| I.; +4 aq.                        | 62.8                                | 101.1                                 | v.s.s. alc.  | d. 645      |                     | 24 |
| V.                                |                                     |                                       |  |             |                     |    |
| IV.                               | 35 (0°)                             | s.                                    | s. ac.   | 3000        |                     | 25 |
| W. cryst.                         | s.s.                                |                                       |  | d. R.H.     | 8 aq <60            | 26 |

| Name                               | Formula.  | Density.        |                       |
|------------------------------------|---|-----------------|-----------------------|
|                                    |   | Formula Weight. | Water=1<br>D:Air=1    |
| 1 Strontium<br>silicofluoride      | $\text{SrSiF}_6 + 2 \text{H}_2\text{O}$         | 265.8           |                       |
| 2 — sulphate                       | $\text{SrSO}_4$                                 | 183.69          | 3.707 ppd.            |
| 3 — sulphide                       | $\text{SrS}$                                    | 119.69          | 3.7                   |
| 4 — thiosulphate                   | $\text{SrS}_2\text{O}_3 + 5 \text{H}_2\text{O}$ | 289.83          | 2.156                 |
| 5 Sulphamide                       | $\text{SO}_2(\text{NH}_2)_2$                    | 96.11           |                       |
| 6 Sulphur, oct.                    | $\text{S}$                                      | 32.06           | 2.0748                |
| 7 —, prism.                        | $\text{S}$                                      | 32.06           | 1.957                 |
| 8 —, amorph.                       | $\text{S}$                                      | 32.06           | 2.046;<br>D:2.23/850° |
| 9 — dichloride                     | $\text{SCl}_2$                                  | 102.98          | 1.62                  |
| 10 — dioxide                       | $\text{SO}_2$                                   | 64.06           | liq. 1.434/0°         |
| 11 — hexafluoride                  | $\text{SF}_6$                                   | 146.06          |                       |
| 12 — hexa-iodide                   | $\text{SI}_6$                                   | 793.58          |                       |
| 13 Sulphuric acid, conc.           | $\text{H}_2\text{SO}_4$ (98.5%)                 |                 | 1.854                 |
| 14 — —, vitriol                    | $\text{H}_2\text{SO}_4$ (92%)                   |                 | 1.835/20°             |
| 15 — —, hydrate                    | $\text{H}_2\text{SO}_4 + \text{H}_2\text{O}$    | 116.10          | 1.788/17°             |
| 16 — —, hydrate                    | $\text{H}_2\text{SO}_4 + 2 \text{H}_2\text{O}$  | 134.11          | 1.665/0°              |
| 17 — —, "monohydrate"              | $\text{H}_2\text{SO}_4$                         | 98.08           | 1.834/18°             |
| 18 — —, pyro                       | $\text{H}_2\text{S}_2\text{O}_7$                | 171.14          | 1.89                  |
| 19 Sulphur monochloride            | $\text{S}_2\text{Cl}_2$                         | 135.04          | 1.706/0°              |
| 20 — monoxytetra-<br>chloride      | $\text{S}_2\text{OCl}_4$                        | 221.96          | 1.656<br>D. 3.86/100° |
| 21 — trioxide                      | $\text{SO}_3$                                   | 80.06           | 1.9546/13°            |
| 22 — —, solid                      | $(\text{SO}_3)_2$                               | 160.12          | 1.040                 |
| 23 — trioxytetrachloride           | $\text{S}_2\text{O}_3\text{Cl}_4$               | 253.96          |                       |
| 24 Sulphuryl chloride              | $\text{SO}_2\text{Cl}_2$                        | 134.98          | 1.66/20°              |
| 25 Tantalum                        | $\text{Ta}$                                     | 181.5           | 16.5                  |
| 26 — chloride                      | $\text{TaCl}_5$                                 | 358.8           |                       |
| 27 — oxide                         | $\text{Ta}_2\text{O}_5$                         | 443.0           | 7.5 am.               |
| 28 Tetraphosphorus<br>monoselenide | $\text{P}_4\text{Se}_2$                         | 282.6           |                       |
| 29 — trisulphide                   | $\text{P}_4\text{S}_3$                          | 220.34          |                       |
| 30 Telluric acid                   | $\text{H}_2\text{TeO}_4 + 2 \text{H}_2\text{O}$ | 229.5           |                       |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       |   | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------------------|-------------------------------------|---------------------------------------|---|-------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) | Alcohol,<br>acids<br>or alkalis         |             |             |    |
|                                   | v.s.                                | v.s.                                  |   |             |             | 1  |
| IV.                               | 0.145                               | 0.01                                  | s.s. ac.                                | d. W.H.     |             | 2  |
| I.                                | d.                                  |                                       | s. alc.                                 |             |             | 3  |
| V.                                | 16.6 (10°)                          | 50                                    | i. alc.                                 | 4 aq 100    |             | 4  |
| IV. plates                        | s.                                  |                                       | s. alc.                                 | 91.5        | d. 250      | 5  |
| IV. Y.                            | i.                                  | i                                     | s.s. alc., s. CS <sub>2</sub>           | 114—115     | 444.6       | 6  |
| V.                                | i.                                  | i                                     | CS <sub>2</sub> , 73 : 100              | 114.4       | 444.6       | 7  |
|                                   | i.                                  | i                                     | i. CS <sub>2</sub>                      | >120        |             | 8  |
|                                   | d.                                  |                                       |   | liq.        | d. 70       | 9  |
| Br.                               | 688                                 | 170                                   | alc. 328                                | -72.7       | -10.1       | 10 |
|                                   | vol. at 0°                          | vol. at 40°                           | vol. at 0°                              |             |             |    |
| W.                                | i.                                  | s.s.                                  | s.s. alc.                               | -55         | -50         | 11 |
| Gr.Bl.cryst                       | d.                                  |                                       | s. CS <sub>2</sub>                      |             |             | 12 |
|                                   | m.                                  | m.                                    | d. alc.                                 | liq.        | 315—317     | 13 |
|                                   | m.                                  | m.                                    | d. alc.                                 | liq.        |             | 14 |
|                                   | m.                                  | m.                                    | d. alc.                                 | +8          | 210—338     | 15 |
|                                   | m.                                  | m.                                    | d. alc.                                 | -70         | 170—190     | 16 |
|                                   | m.                                  | m.                                    | d. alc.                                 | 10.5        | d. 40       | 17 |
| Prism.                            | d.                                  |                                       | d.                                      | 35          |             | 18 |
| Y.                                | d.                                  |                                       | s. CS <sub>2</sub>                      | liq.        | 138         | 19 |
| R.                                | d.                                  |                                       |   | liq.        | 100         | 20 |
| W. needles                        | d.                                  |                                       | d.                                      | 14.8        | 46.2        | 21 |
| W. cryst.                         | d.                                  |                                       |   | 35          |             | 22 |
| W. needles                        | d.                                  |                                       |   | 57          | subl.       | 23 |
|                                   | d.                                  |                                       | s. acetic                               | liq.        | 70.5        | 24 |
| Gr.                               |                                     |                                       |   | 2900        |             | 25 |
| Y.                                | d.                                  |                                       | s. alc.                                 | 221         | 241.6       | 26 |
| Am. W.                            | i.                                  |                                       | s. KHSO <sub>4</sub>                    |             |             | 27 |
|                                   | i.                                  | i.                                    | s. alc., ether,                         | -12         |             | 28 |
|                                   |                                     |                                       | CS <sub>2</sub>                         |             |             |    |
| IV. Y.                            | i.                                  | d.                                    | s. CS <sub>2</sub> , PCl <sub>3</sub> , | 166         | >300        | 29 |
|                                   |                                     |                                       | KHS soln.                               |             |             |    |
| III.                              | s.                                  |                                       | HCl d.                                  | d. R.H.     | 2 aq 160    | 30 |

| Name.                            | Formula.  | Density.        |                            |
|----------------------------------|---|-----------------|----------------------------|
|                                  |   | Formula Weight. | Water=1<br>D:Air=1         |
| 1 Tellurium                      | Te  | 127.5           | D:9/1400°;<br>6.26         |
| 2 — dioxide                      | TeO <sub>2</sub>  | 159.5           | 5.9/0°                     |
| 3 — hydride                      | H <sub>2</sub> Te   | 129.5           |                            |
| 4 — trioxide                     | TeO <sub>3</sub>  | 175.5           | 5.07/15°                   |
| 5 Tellurous acid                 | H <sub>2</sub> TeO <sub>3</sub>                                     | 177.5           |                            |
| 6 Thallie bromide                | TlBr <sub>3</sub>   | 443.8           |                            |
| 7 — chloride                     | TlCl <sub>3</sub> +H <sub>2</sub> O                                 | 328.4           |                            |
| 8 — hydroxide                    | TlO(OH)   | 237.0           |                            |
| 9 — nitrate                      | Tl(NO <sub>3</sub> ) <sub>3</sub> +3 H <sub>2</sub> O               | 444.1           |                            |
| 10 — sulphate                    | Tl <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> +7 H <sub>2</sub> O | 822.3           |                            |
| 11 — sulphide                    | Tl <sub>2</sub> S <sub>3</sub>                                      | 504.2           |                            |
| 12 Thallium                      | Tl  | 204.0           | 11.862                     |
| 13 — monoxide                    | Tl <sub>2</sub> O   | 424.0           |                            |
| 14 — trioxide                    | Tl <sub>2</sub> O <sub>3</sub>                                      | 456.0           | 5.56/0°                    |
| 15 Thallous bromide              | TlBr  | 283.9           | 7.54/22°                   |
| 16 — carbonate                   | Tl <sub>2</sub> CO <sub>3</sub>                                     | 468.0           | 7.164                      |
| 17 — chloride                    | TlCl  | 239.5           | 7.02                       |
| 18 — fluoride                    | TlF   | 223.0           |                            |
| 19 — hydroxide                   | TlOH(+H <sub>2</sub> O)   | 221.0           |                            |
| 20 — iodide                      | TlI   | 330.9           | 7.07                       |
| 21 — nitrate                     | TlNO <sub>3</sub>   | 266.0           | 5.55                       |
| 22 — phosphate                   | Tl <sub>3</sub> PO <sub>4</sub>                                     | 707.0           | 6.89/10°                   |
| 23 — sulphate                    | Tl <sub>2</sub> SO <sub>4</sub>                                     | 504.1           | 6.765                      |
| 24 — sulphide                    | Tl <sub>2</sub> S   | 440.1           | 8                          |
| 25 Thionyl chloride              | SOCl <sub>2</sub>   | 118.98          | 1.676                      |
| 26 Thiophosphoric acid           | PS(OH) <sub>3</sub>   | 114.12          |                            |
| 27 Thiophosphoryl<br>bromide     | PSBr <sub>3</sub>   | 302.86          | 2.85/17°                   |
| 28 — chloride                    | PSCl <sub>3</sub>   | 169.49          | D:5.878/298°;<br>1.6816/0° |
| 29 — triamide                    | PS(NH <sub>2</sub> ) <sub>3</sub>                                   | 111.18          | 1.7/13°                    |
| 30 Thiopyrophosphoryl<br>bromide | P <sub>2</sub> S <sub>3</sub> Br <sub>4</sub>                       | 477.94          | 2.262/17°                  |
| 31 Thorium chloride              | ThCl <sub>4</sub>   | 374.2           | 4.59                       |
| 32 — nitrate                     | Th(NO <sub>3</sub> ) <sub>4</sub>                                   | 480.4           |                            |

| Crystalline<br>form and<br>colour | Solubility*in                        |  | Alcohol,<br>acids<br>or alkalies | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------------------|--------------------------------------|--|----------------------------------|-------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C (60°F) | 100 parts<br>water at<br>100°C (212°F) |                                  |             |             |    |
| Gr. W.                            | i.                                   | i                                      | s. $H_2SO_4$                     | 450         | 1390        | 1  |
| Y.                                | i.                                   |  |                                  | dark R.H.   | <700        | 2  |
|                                   | s.                                   |  | s. alc.                          | -54         |             | 3  |
| Y, cryst.                         | i.                                   |  |                                  |             | d. R.H      | 4  |
|                                   | s.s.                                 | d.                                     |                                  | d. 40       |             | 5  |
| Y, needles                        | s.                                   | s.                                     | s. alc.                          | d.          |             | 6  |
|                                   | v.s.                                 | d.                                     |                                  | aq 60       | d. 100      | 7  |
| Y, cryst.                         | s.                                   |  | s. alc.                          | d. 100      |             | 8  |
| O, cryst.                         | deliq.                               | d.                                     |                                  | d. 100      |             | 9  |
| O, cryst.                         | d                                    |  |                                  | 6 aq 220    | d.          | 10 |
| Am. Bl.                           | i.                                   | i                                      | s.h. $H_2SO_4$                   |             | d.          | 11 |
| Am.                               | i.                                   |  | S. $HNO_3$                       | 302         | 1280        | 12 |
| Bl.                               | s.                                   |  | s. ac.                           | 300         |             | 13 |
| II. Bl.                           | i.                                   | i                                      | s. HCl                           |             |             | 14 |
| W.                                |                                      |  |                                  | 460         |             | 15 |
| V.                                | 5.2                                  | 22.4                                   | i.                               | d. 272      |             | 16 |
| W                                 | 0.265                                | 1.427                                  | i. HCl, alc.                     | 451         | 719—731     | 17 |
| Oct.                              | 80                                   | <80                                    |                                  |             |             | 18 |
|                                   | s.                                   |  |                                  | d. 100      |             | 19 |
| Y.                                | 0.00625                              | 0.125                                  | s. $HNO_3$                       | 439         | 800—806     | 20 |
| V.                                | 10.6                                 | 508/108°                               | i. alc.                          | 205         |             | 21 |
| W.                                | 0.5                                  | 0.75                                   | i. alc.                          |             |             | 22 |
| V.                                | 4.8                                  | 19.3                                   |                                  | 632         | d.          | 23 |
| Br.                               | i.                                   | i                                      | s. ac.                           | d.          |             | 24 |
|                                   | d.                                   |  |                                  | liq.        | 78.8        | 25 |
|                                   | s.                                   | d.                                     | s. alc.                          |             |             | 26 |
| l.                                | d.                                   |  | s. $CS_2$                        | 38          | d.          | 27 |
|                                   | d.                                   |  |                                  | liq.        | 126         | 28 |
| V.                                | s.s.                                 | d.                                     | s. alc.                          | d. 200      |             | 29 |
| l.                                | d.                                   |  |                                  | liq.        | d.          | 30 |
| V, plates                         | deliq.                               |  |                                  | 520         | subl.       | 31 |
| plates                            | deliq.                               |  | s. alc.                          |             |             | 32 |

| Name.                           | Formula.   | Density.        |                    |
|---------------------------------|--|-----------------|--------------------|
|                                 |  | Formula Weight. | Water=1<br>D:Air=1 |
| 1 Thorium oxide                 | $\text{ThO}_2$                                     | 264.4           | 9.87/15° cry       |
| 2 Tin                           | $\text{Sn}$  | 118.7           | 7.29               |
| 3 Titanium                      | $\text{Ti}$  | 48.1            | 3.45, fus. 4       |
| 4 — dioxide                     | $\text{TiO}_2$                                     | 80.1            | 3.7—4.2            |
| 5 — tetrachloride               | $\text{TiCl}_4$                                    | 189.9           | 1.76/0°            |
| 6 Triphosphonitrile<br>chloride | $\text{P}_3\text{N}_3\text{Cl}_6$                  | 347.91          | 1.98               |
| 7 Tungsten                      | $\text{W}$   | 184.0           | 19.13              |
| 8 — dioxide                     | $\text{WO}_2$                                      | 216.0           | 12.1               |
| 9 — hexachloride                | $\text{WCl}_6$                                     | 396.8           | D:13.3/350°        |
| 10 — pentachloride              | $\text{WCl}_5$                                     | 361.3           | 3.52               |
| 11 — trioxide                   | $\text{WO}_3$                                      | 232.0           | 7.16 am.           |
| 12 — trisulphide                | $\text{WS}_3$                                      | 280.2           |                    |
| 13 Tungstic acid hydrate        | $\text{H}_2\text{WO}_4 + \text{H}_2\text{O}$       | 268.0           |                    |
| 14 Uranium                      | $\text{U}$   | 238.2           | 18.68              |
| 15 — oxide                      | $\text{UO}_2$                                      | 270.2           | 10.9               |
| 16 — sulphate                   | $\text{U}(\text{SO}_4)_2 + 8\text{H}_2\text{O}$    | 574.5           |                    |
| 17 — tetrachloride              | $\text{UCl}_4$                                     | 380.0           |                    |
| 18 Uranyl chloride              | $\text{UO}_2\text{Cl}_2$                           | 341.1           |                    |
| 19 — nitrate                    | $\text{UO}_2(\text{NO}_3)_2 + 6\text{H}_2\text{O}$ | 502.3           | 2.81               |
| 20 — phosphate                  | $\text{UO}_2(\text{HPO}_4) + 4\text{H}_2\text{O}$  | 438.3           |                    |
| 21 — sulphate                   | $2\text{UO}_2\text{SO}_4 + 7\text{H}_2\text{O}$    | 859.6           |                    |
| 22 Vanadic acid, meta           | $\text{HVO}_3$                                     | 100.0           |                    |
| 23 Vanadium                     | $\text{V}$   | 51.0            | 5.5                |
| 24 — dichloride                 | $\text{VOCl}_2$                                    | 121.9           | 3.23               |
| 25 — monosulphide               | $\text{V}_2\text{S}_2$                             | 166.1           | 4.2—4.4            |
| 26 — monoxide                   | $\text{VO}$  | 134.0           | 3.64               |
| 27 — pentoxide                  | $\text{V}_2\text{O}_5$                             | 182.0           | 3.5/20°            |
| 28 — sesquioxide                | $\text{V}_2\text{O}_3$                             | 150.0           | 4.72/16°           |
| 29 — sesquisulphide             | $\text{V}_2\text{S}_3$                             | 198.2           | 3.7, 4.0           |
| 30 — tetrachloride              | $\text{VCl}_4$                                     | 192.8           | 1.8585             |
| 31 — trichloride                | $\text{VCl}_3$                                     | 157.4           | 3/18°              |



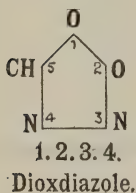
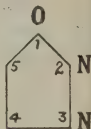
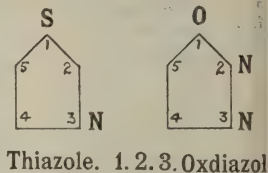
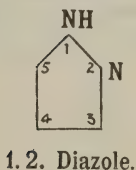
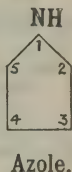
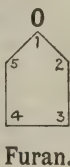
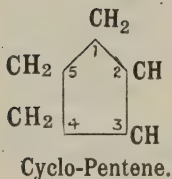
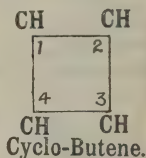
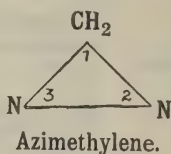
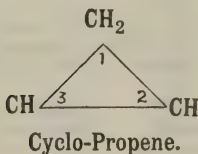
| Crystalline form and colour   |                                 | Solubility*in |  | Alcohol, acids or alkalis | M.P. °C.    | B.P. °C. |    |
|-------------------------------|---------------------------------|---------------|--|---------------------------|-------------|----------|----|
| 100 parts water at 15°C(60°F) | 100 parts water at 100°C(212°F) |               |  |                           |             |          |    |
| I. Am. W.                     | i.                              |               |  | s. conc. $H_2SO_4$        | infusible   |          | 1  |
| W. cryst.                     | i.                              |               |  | s.h. ac.                  | 231.9       | W.H.     | 2  |
| Gr.                           |                                 | d.            |  | s. HCl                    | 1800—1850   |          | 3  |
| II. IV.                       | i.                              |               |  |                           | 1500        |          | 4  |
|                               | s.                              | d.            |  |                           | - 25        | 136      | 5  |
|                               | i. d.                           |               |  | s. alc., ether            | 114         | 250      | 6  |
| III. Gr. W                    | i.                              |               |  | s. $HNO_3$                | 3000±100    |          | 7  |
| Br.                           | i.                              |               |  | s.s.ac., s.KOH            |             |          | 8  |
| Viol. Bl.                     | d. 60°                          |               |  | s. $CS_2$                 | 275         | 346.7    | 9  |
| Bl. cryst.                    | deliq.                          |               |  |                           | 248         | 275.6    | 10 |
| IV. Y.                        | i.                              |               |  | s. alk.                   | R.H.        |          | 11 |
| Bl.                           | s.s.                            | s.            |  | s. alk.                   |             |          | 12 |
| V.                            | s.s.                            |               |  | s. alk.                   | at 100 :    |          | 13 |
|                               |                                 |               |  |                           | $H_2W_2O_7$ |          |    |
| I. W.                         | i.                              | f             |  | s. ac.                    | W.H.        |          | 14 |
| II. G., Bl.                   | i.                              | i             |  | i. conc. $H_2SO_4$        | oxid.       |          | 15 |
| Bl. cryst.                    | s.                              |               |  | i. alc.                   | d.          |          | 16 |
| III. G.                       | v.s.                            | s.            |  | s. alc.                   | gas         |          | 17 |
| IV. Br. Bl.                   | 320 (18°)                       | s.            |  | s. alc., ether            | fusible     | d.       | 18 |
| V. cryst                      | (+6aq.)200                      | v.s.          |  | v.s. alc.                 | 59.5        | 118      | 19 |
| VI. Y.                        | i.                              | i             |  | i. acetic acid            | aq 60       |          | 20 |
| VII.                          | v.s.                            | v.s.          |  | s. $H_2SO_4$              | an. 300     |          | 21 |
| VIII. Br.                     | s.                              | s.            |  |                           |             |          | 22 |
| IX. Cryst.                    |                                 |               |  | s. $HNO_3$ , conc.        | 1730        |          | 23 |
|                               |                                 |               |  | $H_2SO_4$                 |             |          |    |
| X. Y.                         | s.                              | s.            |  | s. alc.                   |             |          | 24 |
| XI. Bl.                       |                                 |               |  | i. HCl,                   |             |          | 25 |
|                               |                                 |               |  | s. h. $H_2SO_4$           |             |          |    |
| XII. pdr.                     | i.                              | i             |  | s. ac.                    |             |          | 26 |
| XIII. V. R.                   | 1:1000                          |               |  | s. ac., alk.              | 658         |          | 27 |
| XIV. Bl.                      | s.                              | s.            |  | s. $HNO_3$ , i.alk.       | infusible   |          | 28 |
| XV. Bl. plates,               |                                 |               |  | s.s. conc. ac.            |             |          | 29 |
| XVI. Gr. pdr.                 |                                 |               |  | s. am. sulph.             |             |          |    |
| XVII. Br.                     | s.                              |               |  |                           | - 18 liq.   | 154      | 30 |
| XVIII. Bl. plates             | deliq.                          |               |  | s. alc.                   |             |          | 31 |

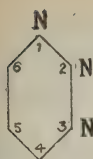
| Name                  | Formula                | Density.        |                                       |
|-----------------------|------------------------|-----------------|---------------------------------------|
|                       |                        | Formula Weight. | Water=1<br>D: Air=1                   |
| 1 Vanadyl sulphate    | $(VO)_2(SO_4)_3$       | 422.2           |                                       |
| 2 — trichloride       | $VOCl_3$               | 173.4           | 1.841                                 |
| 3 Water               | $H_2O$                 | 18.016          | 0.9568 100°/4<br>ice 0.91674<br>0°/0° |
| 4 Yttrium oxide       | $Y_2O_3$               | 225.4           | 5.046                                 |
| 5 — nitrate           | $Y(NO_3)_3 + 6 H_2O$   | 382.8           |                                       |
| 6 Zinc                | $Zn$                   | 65.37           | 6.86—7.21<br>D: 2.26/1400             |
| 7 — bromate           | $Zn(BrO_3)_2 + 6 H_2O$ | 429.31          |                                       |
| 8 — bromide           | $ZnBr_2$               | 225.31          | 3.643                                 |
| 9 — carbonate         | $ZnCO_3 + H_2O$        | 143.39          | 4.42                                  |
| 10 — chlorate         | $Zn(ClO_3)_2 + 6 H_2O$ | 340.39          |                                       |
| 11 — chloride         | $ZnCl_2$               | 136.29          | 2.91/25°                              |
| 12 — hydroxide        | $Zn(OH)_2$             | 99.39           | 2.877                                 |
| 13 — iodide           | $ZnI_2$                | 319.21          | 4.696                                 |
| 14 — nitrate          | $Zn(NO_3)_2 + 6 H_2O$  | 297.49          |                                       |
| 15 — oxide            | $ZnO$                  | 81.37           | 5.61                                  |
| 16 — phosphate        | $Zn_3(PO_4)_2$         | 386.19          | 3.99/15°                              |
| 17 — sulphate         | $ZnSO_4 + 7 H_2O$      | 287.54          | 1.96; 3.4 an.                         |
| 18 — sulphide         | $ZnS$                  | 97.43           | 4.0                                   |
| 19 Zirconium chloride | $ZrCl_4$               | 232.4           |                                       |
| 20 — fluoride         | $ZrF_4$                | 166.6           | 4.433                                 |
| 21 — oxide            | $ZrO_2$                | 122.6           | 5.1—5.7                               |

| Crystalline<br>form and<br>colour | Solubility*in                       |                                       |                                  | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------------------|-------------------------------------|---------------------------------------|----------------------------------|-------------|-------------|----|
|                                   | 100 parts<br>water at<br>15°C(60°F) | 100 parts<br>water at<br>100°C(212°F) | Alcohol,<br>acids<br>or alkalies |             |             |    |
| B.                                | deliq.                              |                                       |                                  |             |             | 1  |
| Y.                                | d.                                  |                                       |                                  | -15 liq.    | 126.7       | 2  |
| III.                              |                                     |                                       | m. alc.                          | 0           | 100         | 3  |
| W. cryst.                         | i.                                  |                                       | s. mineral ac.                   |             |             | 4  |
| C. plates                         | deliq.                              |                                       | s. alc., ether                   | 17, -6 aq   |             | 5  |
| III., W.                          | i.                                  | slight d                              | s. ac.                           | 419.4       | 930         | 6  |
|                                   | s.                                  | s.                                    |                                  | 100         | 6 aq 200    | 7  |
|                                   | s.                                  | s.                                    | s. alc., ether                   | 390         | 695         | 8  |
| IIa, an.                          | i.                                  | i                                     | i. alc.                          | d. 300      |             | 9  |
| I. W.                             | s.                                  | s.                                    | s. alc.                          | 60          |             | 10 |
| W. cryst.                         | 330 (10°)                           | v.s.                                  | alc. 1:1                         | 262         | 730         | 11 |
| V;+aq.I                           | i.                                  | i                                     | s. alk., ac.                     | d.          |             | 12 |
|                                   | deliq.                              | v.s.                                  | s. alc.                          | d.          |             | 13 |
| I.                                | deliq.                              | v.s.                                  | s. alc.                          | 36.4        | 6 aq 105    | 14 |
| II. W.                            | 1:100000                            |                                       | s. alc.                          | W.H.        |             | 15 |
| Prism.                            |                                     | 655                                   |                                  | R.H.        |             | 16 |
| V.                                | (+7aq.)135                          |                                       | i.                               | 6 aq 100    | aq R.H.     | 17 |
| .. W.                             | i.                                  | i                                     | s. ac.                           | 1049        |             | 18 |
| V.                                | v.s.                                | s. d.                                 | s. alc.                          |             |             | 19 |
| II. C.                            | i.                                  |                                       | i. ac.                           | W.H.        |             | 20 |
| I., V                             | i.                                  |                                       | s. conc. H <sub>2</sub> SO       |             |             | 21 |

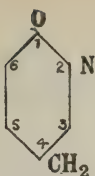
# Nomenclature of Organic Compounds (Richter).

In numbering positions in the case of substitution derivatives of phenol, aniline, toluene, etc., the characteristic radical of each of these substances is regarded as in position 1.

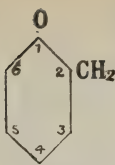




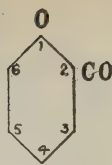
1. 2. 3. Triazole.



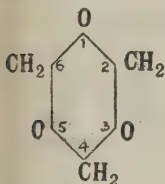
1. 2. Oxazine (4)



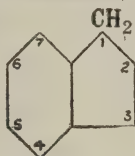
1. 2. Pyran.



1. 2. Pyrone.



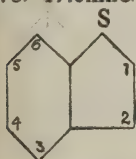
1. 2. 3. Trioxine.



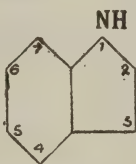
Indene.



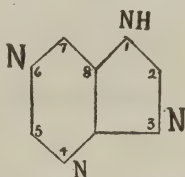
Benzfuran.



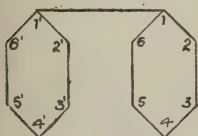
Benzthiofuran.



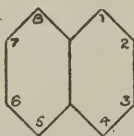
Benzazole.



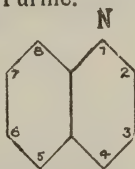
Purine.



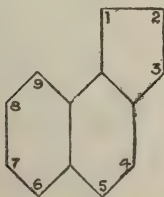
Diphenyl.



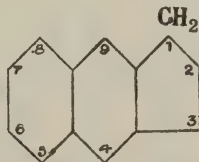
Naphthalene.



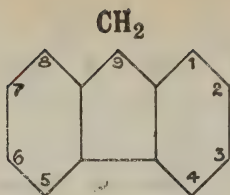
1. Benzazine.



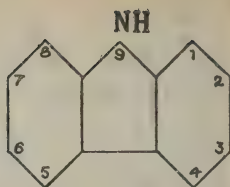
$\alpha$ -Naphthindene



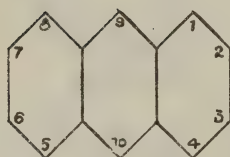
$\beta$ -Naphthindene.



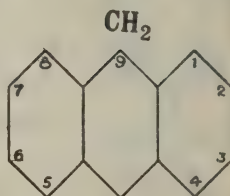
Fluorene.



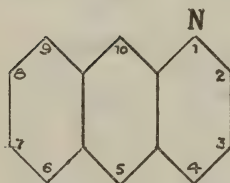
Carbazole.



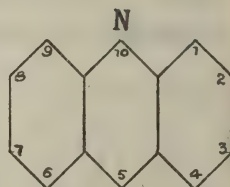
Anthracene.



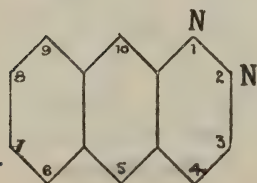
**O**  
Xanthene.



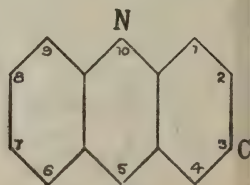
Anthrapyridine.



Acridine.

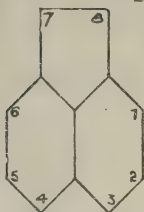


1,2. Naphthdiazine.

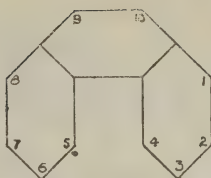


**NH**  
Phenoxazine.

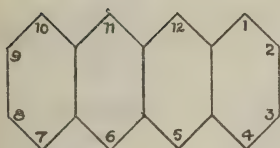
$\text{CH}_2$        $\text{CH}_2$



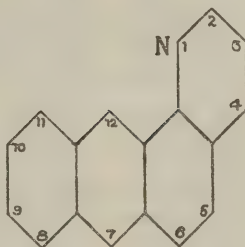
Acenaphthene.



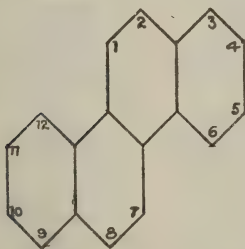
Phenanthrene.



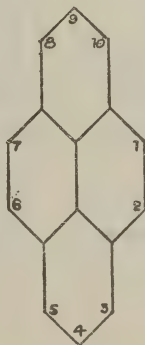
Naphthacene.



$\alpha$ -Anthraquinoline.



Chrysene.



Pyrene.

## GENERAL PROPERTIES OF

Salts and esters follow the corresponding organic acids. Most *iso* are given in alphabetical order. For numbering of position

| Name.                          | Formula.                  | Formula Empirical Weight. | Formula.                 |
|--------------------------------|---------------------------|---------------------------|--------------------------|
| 1 Abietic acid                 | $C_{20}H_{30}O_2$         | 303.32                    | $C_{20}H_{30}O_2$        |
| 2 Acenaphthene                 | $C_{10}H_6:(CH_2.CH_2)_2$ | 154.14                    | $C_{12}H_{10}$           |
| 3 Acenaphthylene               | $C_{10}H_6:(CH:CH)_2$     | 152.12                    | $C_{12}H_8$              |
| 4 Acetal                       | $CH_3.CH:(OC_2H_5)_2$     | 118.14                    | $C_6H_{14}O_2$           |
| 5 Acetaldehyde                 | $CH_3.CHO$                | 44.04                     | $C_2H_4O$                |
| 6 — ammonia                    | $CH_3.CHOH.NH_2$          | 61.08                     | $C_2H_7ON$               |
| 7 — cyanhydrin                 | $CH_3.CH(OH)CN$           | 71.06                     | $C_2H_7ON$               |
| 8 — phenyl hydrazone, $\alpha$ | $CH_3.CH:N.NH.C_6H_5$     | 134.14                    | $C_8H_{10}N_2$           |
| 9 — — —, $\beta$               | " "                       | 134.14                    | " "                      |
| 10 — semi-carbazone            | $CH_3.CH:N.NH.CO.NH_2$    | 87.09                     | $C_3H_7ON_3$             |
| 11 Acetaldoxime                | $CH_3.CH:NOH$             | 59.06                     | $C_2H_5ON$               |
| 12 Acetamide                   | $CH_3.CO.NH_2$            | 59.06                     | $C_2H_5ON$               |
| 13 — chloride                  | $CH_3.CCl.NH_2$           | 113.98                    | $C_2H_5NCl_2$            |
| 14 Acetamidine                 | $CH_3.C(NH)NH_2$          | 58.08                     | $C_2H_5N_2$              |
| 15 Acetamino phenol            | $CH_3.CONH.C_6H_4.OH$     | 151.12                    | $C_8H_9ON$               |
| 16 Acetanilide                 | $C_6H_5.NH.COCH_3$        | 135.12                    | $C_8H_9ON$               |
| 17 Acetic acid                 | $CH_3.COOH$               | 60.04                     | $C_2H_4O_2$              |
| 18 Acetate, ammonium           | $CH_3COONH_4$             | 77.08                     | $C_2H_7O_2N$             |
| 19 — calcium                   | $(CH_3COO)_2Ca.2H_2O$     | 194.17                    | $C_4H_6O_4Ca$            |
| 20 — cupric                    | $(CH_3COO)_2Cu.H_2O$      | 199.66                    | $C_4H_6O_4Cu$            |
| 21 — ferric                    | $(CH_3COO)_3Fe_2$         | 465.88                    | $C_{12}H_{18}O_{12}Fe_2$ |
| 22 — lead                      | $(CH_3COO)_4Pb$           | 443.34                    | $C_8H_{12}O_8Pb$         |
| 23 — — (sugar of lead)         | $(CH_3COO)_2Pb.3H_2O$     | 379.32                    | $C_4H_6O_4Pb$            |
| 24 — — basic                   | $CH_3COO.PbO.PbOH$        | 506.44                    | $C_4H_4O_4Pb_2$          |
| 25 — potassium                 | $CH_3COOK$                | 98.13                     | $C_2H_3O_2K$             |
| 26 — sodium                    | $CH_3COONa.3H_2O$         | 136.08                    | $C_2H_3O_2Na$            |
| 27 — uranyl                    | $(CH_3COO)_2UO_2.3H_2O$   | 442.32                    | $C_4H_6O_8U$             |
| 28 — zinc                      | $(CH_3COO)_2Zn.3H_2O$     | 223.47                    | $C_4H_6O_8Zn$            |
| 29 — allyl                     | $CH_3COOC_3H_5$           | 100.09                    | $C_5H_8O_2$              |
| 30 — amyl                      | $CH_3COOC_5H_{11}$        | 130.15                    | $C_7H_{14}O_2$           |
| 31 — benzyl                    | $CH_3COOC_7H_7$           | 150.13                    | $C_9H_{10}O_2$           |
| 32 — bornyl, $d$               | $CH_3.COOC_{10}H_{17}$    | 196.22                    | $C_{12}H_{20}O_2$        |
| 33 — ethyl                     | $CH_3COOC_2H_5$           | 88.08                     | $C_4H_8O_2$              |



## ORGANIC COMPOUNDS.

compounds follow the corresponding *normal* compounds. Substituents in cyclic compounds, see "Notation of Organic Compounds."

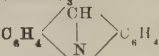
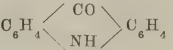
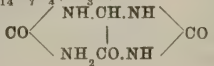
| Density<br>H <sub>2</sub> O=1. | Solubility in |          |                | M.P.<br>°C.  | B.P.<br>°C.   |    |
|--------------------------------|---------------|----------|----------------|--------------|---------------|----|
|                                | Water.        | Alcohol. | Ether.         |              |               |    |
|                                | i.            | s.       | s.s. acetic    | 161          |               | 1  |
| 1.03                           |               | c.s.s.   |                | 95           | 277.5         | 2  |
|                                | i.            | v.s.     | v.s.           | 93           | 265—275 d.    | 3  |
| 0.821/22°                      | c. 1 : 18     | v.s.     | s.             | liq.         | 104           | 4  |
| 0.778/16°                      | v.s.          | s.       | s.             | - 120.7      | 20.8          | 5  |
|                                | s.            |          | s.s.           | 96—98        | 100           | 6  |
|                                | v.s.          | v.s.     |                |              | 182—184 d.    | 7  |
|                                |               |          | 1 : 20 ligroin | 98           | 236—237/20mm. | 8  |
|                                |               | s.       | 1 : 6 ligroin  | 56           | 133—136/20mm. | 9  |
|                                | s.s.          | s.s.     |                | 162          |               | 10 |
|                                | m.            | m.       | m.             | 45           | 114—115       | 11 |
| 1.159                          | v.s.          | v.s.     | v.s.           | 83           | 215.5/749mm.  | 12 |
|                                | d.            |          |                |              | 88—89/762mm.  | 13 |
|                                | d.            |          | s. ac.         |              |               | 14 |
| 1.293/21°                      | h.v.s.s.      | c.v.s.   |                | 166—167      |               | 15 |
| 1.21/4°                        | 1 : 189       | s.       | s.             | 113 (corr.)  | 283           | 16 |
| 1.05704/15°                    | m.            | s.       | s.             | 16.68        | 117.88        | 17 |
| 1.073                          | v.s.          |          |                | 120          |               | 18 |
|                                | s.            | s.s.     |                | 100 an.      |               | 19 |
| 1.882                          | h. 1 : 5      | 1 : 14   |                | 100 an.      | d. 240        | 20 |
|                                | s.            | s.       |                |              |               | 21 |
|                                |               |          |                | 175          |               | 22 |
| 2.496                          | c. 1 : 1.5    | s.       |                | 75, an. 280  |               | 23 |
|                                | 1 : 18        | s.s.     |                |              |               | 24 |
|                                | del. 1 : 0.5  | c. 1 : 3 | i.             | 292          | d. R.H.       | 25 |
| 1.42                           | 1 : 2.8       | s.s.     |                | 58, an. 319  |               | 26 |
|                                | s.            | s.       |                | aq. 100, 275 |               | 27 |
| 1.735                          | v.s.          |          |                | 235—237      | 3 aq. 100     | 28 |
| 0.9376/0°                      |               | s.       |                | liq.         | 105           | 29 |
| 0.879/20°                      | i.            | s.       | s.             | liq.         | 148           | 30 |
| 1.057/16.5°                    |               |          |                | liq.         | 215.3/756mm.  | 31 |
|                                |               |          |                | 29           | 221           | 32 |
| 0.9048/0°                      | 1 : 17/17.5°  | m.       | m.             | - 82.8       | 77.2          | 33 |

| Name.                        | Formula.   | Formula Empirical |  |
|------------------------------|--|-------------------|--|
|                              |  | Weight.           | Formula.                                       |
| 1 Acetate, ethylene          | $(\text{CH}_3\text{COO})_2:\text{C}_2\text{H}_4$                         | 146.11            | $\text{C}_6\text{H}_{10}\text{O}_4$            |
| 2 — hexyl                    | $\text{CH}_3\text{COOC}_6\text{H}_{13}$                                  | 144.17            | $\text{C}_8\text{H}_{16}\text{O}_2$            |
| 3 — methyl                   | $\text{CH}_3\text{COOCH}_3$  | 74.06             | $\text{C}_3\text{H}_6\text{O}_2$               |
| 4 — methylene                | $(\text{CH}_3\text{COO})_2:\text{OH}_2$                                  | 132.09            | $\text{C}_5\text{H}_8\text{O}_4$               |
| 5 — naphthyl, $\alpha$       | $\text{CH}_3\text{COOC}_{10}\text{H}_7$                                  | 186.14            | $\text{C}_{12}\text{H}_{10}\text{O}_2$         |
| 6 — — $\beta$                | " "  | 186.14            | " "  |
| 7 — phenyl                   | $\text{CH}_3\text{COOC}_6\text{H}_5$                                     | 136.10            | $\text{C}_8\text{H}_8\text{O}_2$               |
| 8 Acetic anhydride           | $(\text{CH}_3\text{CO})_2:\text{O}$                                      | 102.07            | $\text{C}_4\text{H}_6\text{O}_3$               |
| 9 Acetin, mono               | $(\text{OH})_2:\text{O}_2\text{H}_5.\text{O.COCH}_3$                     | 134.11            | $\text{C}_5\text{H}_{10}\text{O}_4$            |
| 10 Acetnaphthalide, $\alpha$ | $\text{C}_{10}\text{H}_7.\text{NH.COCH}_3$                               | 185.16            | $\text{C}_{12}\text{H}_{11}\text{ON}$          |
| 11 — $\beta$                 | " "  | 185.16            | " "  |
| 12 $\gamma$ eto-acetanilide  | $\text{CH}_3\text{CO.CH}_2\text{CO.NH.C}_6\text{H}_5$                    | 177.15            | $\text{C}_{10}\text{H}_{11}\text{O}_2\text{N}$ |
| 13 — acetic acid             | $\text{CH}_3\text{CO.CH}_2\text{COOH}$                                   | 102.07            | $\text{C}_4\text{H}_6\text{O}_3$               |
| 14 — — —, ethyl ester        | $\text{CH}_3\text{CO.CH}_2\text{COOC}_2\text{H}_5$                       | 130.11            | $\text{C}_6\text{H}_{10}\text{O}_3$            |
| 15 — benzidine               | $\text{NH}_2.\text{C}_6\text{H}_4.\text{C}_6\text{H}_4.\text{NH.COCH}_3$ | 226.20            | $\text{C}_{14}\text{H}_{14}\text{ON}_2$        |
| 16 — diphenylamine           | $(\text{C}_6\text{H}_5)_2:\text{N.COCH}_3$                               | 211.18            | $\text{C}_{14}\text{H}_{13}\text{ON}$          |
| 17 — toluide, $o$            | $\text{C}_7\text{H}_7.\text{NH.COCH}_3$                                  | 149.14            | $\text{C}_9\text{H}_{11}\text{ON}$             |
| 18 — — $m$                   | " "  | 149.14            | " "  |
| 19 — — $p$                   | " "  | 149.14            | " "  |
| 20 Acetol                    | $\text{CH}_3\text{CO.CH}_2\text{OH}$                                     | 74.06             | $\text{C}_3\text{H}_6\text{O}_2$               |
| 21 Aceton acid, see          | Hydroxy butyric acid   |                   |  |
| 22 Acetone                   | $\text{CH}_3\text{COCH}_3$   | 58.06             | $\text{C}_3\text{H}_6\text{O}$                 |
| 23 — chloride                | $\text{CH}_3\text{CCl}_2\text{CH}_3$                                     | 100.98            | $\text{C}_2\text{H}_4\text{Cl}_2$              |
| 24 — cyanhydrin              | $(\text{CH}_3)_2\text{C}(\text{OH})\text{CN}$                            | 85.09             | $\text{C}_3\text{H}_5\text{ON}$                |
| 25 — diacetic acid           | $\text{CO}:(\text{CH}_2.\text{CH}_2\text{COOH})_2$                       | 174.12            | $\text{C}_7\text{H}_{10}\text{O}_5$            |
| 26 — dicarboxylic acid       | $\text{CO}:(\text{CH}_2\text{COOH})_2$                                   | 146.07            | $\text{C}_5\text{H}_8\text{O}_5$               |
| 27 — phenylhydrazone         | $(\text{CH}_3)_2:\text{C}:\text{N.NH.C}_6\text{H}_5$                     | 148.15            | $\text{C}_9\text{H}_{12}\text{N}_2$            |
| 28 — semicarbazone           | $(\text{CH}_3)_2:\text{C}:\text{N.NH.CONH}_2$                            | 115.12            | $\text{C}_4\text{H}_9\text{ON}_3$              |
| 29 Acetonitrile              | $\text{CH}_3\text{CN}$   | 41.04             | $\text{C}_2\text{H}_3\text{N}$                 |
| 30 Acetonyl acetone          | $\text{CH}_3\text{CO.CO.CH}_2\text{CH}_2\text{CH}_3$                     | 116.13            | $\text{C}_6\text{H}_{12}\text{O}_2$            |
| 31 Acetonylurea              | $\text{C}_5\text{H}_9\text{N}_2\text{O}_2$                               | 123.07            | $\text{C}_5\text{H}_9\text{N}_2\text{O}_2$     |
| 32 Acetophenine              | $\text{C}_6\text{H}_5\text{N}$   | 321.28            | $\text{C}_6\text{H}_5\text{N}$                 |
| 33 Acetophenone              | $\text{C}_6\text{H}_5.\text{COCH}_3$                                     | 120.10            | $\text{C}_8\text{H}_8\text{O}$                 |
| 34 — acetone                 | $\text{C}_6\text{H}_5.\text{COCH}_2.\text{CH}_2\text{COCH}_3$            | 176.15            | $\text{C}_{11}\text{H}_{12}\text{O}_2$         |
| 35 — carboxylic acid, see    | Acetyl benzoic acid  |                   |  |
| 36 Acetoxime                 | $(\text{OH})_2:\text{C}:\text{NOH}$                                      | 73.08             | $\text{C}_3\text{H}_7\text{ON}$                |
| 37 Aceturic acid, see        | Acetyl glycine   |                   |  |
| 38 Acetyl acetone            | $\text{CH}_3\text{CO.CH}_2\text{COCH}_3$                                 | 100.09            | $\text{C}_5\text{H}_8\text{O}_3$               |
| 39 — amino benzoic acid, $o$ | $\text{CH}_3\text{CO.NH.C}_6\text{H}_4\text{COOH}$                       | 179.13            | $\text{C}_9\text{H}_9\text{O}_3\text{N}$       |

| Density<br>H <sub>2</sub> O=1. | Solubility in |          |           | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|---------------|----------|-----------|-------------|-------------|----|
|                                | Water.        | Alcohol. | Ether.    |             |             |    |
| >H <sub>2</sub> O              | s.s.          | s.       | s.        | liq.        | 185         | 1  |
| 0.8902/0°                      |               |          |           | liq.        | 169.2       | 2  |
| 0.957/0°                       | s.            | s.       |           | -101.2      | 56.95       | 3  |
| aq.                            |               |          |           | liq.        | 169—171/745 | 4  |
|                                | d.            | s.       | a.        | 46          |             | 5  |
|                                | i.            | s.       | s.        | 70          |             | 6  |
| 1.0809/15°                     |               |          |           |             | 190         | 7  |
| 1.0757/21°                     |               |          |           | liq.        | 137.9       | 8  |
| 1.20                           |               |          |           | 131/2-3mm.  |             | 9  |
|                                | h.s.          | v.s.     |           | 159         |             | 10 |
|                                | h.v.s.        | s.       |           | 132         |             | 11 |
|                                | s.s.          | s.       | s.        | 85          |             | 12 |
|                                | v.s.          |          |           | liq.        | d. 100      | 13 |
| 1.0282/20°                     | s.s.          |          |           | < -80       | 181         | 14 |
|                                | i.            | v.s.     | i.        | 38—40       |             | 15 |
|                                |               |          | s.        | 103         |             | 16 |
|                                | 0.86 : 100    | s.       |           | 112—115     | 296         | 17 |
|                                | 0.44 : 100    | s.       |           | 65.5        | 303         | 18 |
|                                | 0.06 : 100    | s.       |           | 147         | 307         | 19 |
|                                | m.            | m.       | m.        |             | 147         | 20 |
|                                |               |          |           |             |             | 21 |
| 0.7971/15°                     | m.            | m.       | m.        | -94.9       | 56.1        | 22 |
| 1.827/16°                      |               |          |           | -34.6       | 69.6        | 23 |
|                                |               |          |           | -19.5       | 120         | 24 |
|                                | s.s.          | s.       | s.s.      | 142—143     |             | 25 |
| 1.1107/20°                     | v.s.          | v.s.     | v.s.      | 135         | d. 250      | 26 |
|                                |               | v.s.     |           | 15—16       | 165/91mm    | 27 |
|                                |               |          |           | 190—191     |             | 28 |
| 0.7891                         | m.            | s.       |           |             | 93          | 29 |
|                                | m.            | m.       | m.        | -9          | 190—191     | 30 |
| 0.8018/4°                      | v.s.          | v.s.     | v.s.      | -41         | 175         | 31 |
|                                |               | s.s.     |           | 135         |             | 32 |
| 1.0272/20°                     | s.s.          |          |           | 20.8        | 201.5       | 33 |
|                                | c.s.s.        |          |           |             | d.          | 34 |
|                                |               |          |           |             |             | 35 |
|                                | v.s.          | v.s.     | v.s.      | 60          | 135         | 36 |
|                                |               |          |           |             |             | 37 |
| 0.9745/20°                     | 1 : 8         | s.       | s.        |             | 139—746mm.  | 38 |
|                                | c.s.s.        | s.       | s. acetic | 185         |             | 39 |

| Name.                                 | Formula.  | Formula Weight. | Empirical Formula.                               |
|---------------------------------------|---|-----------------|--|
| 1 Acetyl amino benzoic acid, <i>m</i> | $\text{CH}_3\text{CO.NH.C}_6\text{H}_4\text{COOH}$            | 179.13          | $\text{C}_9\text{H}_9\text{O}_3\text{N}$         |
| 2 ———— <i>p</i>                       | " "   | 179.13          | " "  |
| 3 — phenol, <i>o</i>                  | $\text{CH}_3\text{CO.NH.C}_6\text{H}_4\text{OH}$              | 151.12          | $\text{C}_8\text{H}_9\text{O}_2\text{N}$         |
| 4 — benzoic acid, <i>o</i>            | $\text{CH}_3\text{CO.C}_6\text{H}_4\text{COOH}$               | 164.11          | $\text{C}_9\text{H}_8\text{O}_3$                 |
| 5 ———, <i>p</i>                       | " "   | 164.11          | " "  |
| 6 — bromide                           | $\text{CH}_3\text{CO.Br}$                                     | 122.95          | $\text{C}_2\text{H}_3\text{OBr}$                 |
| 7 — carbazole, 9                      | $\text{C}_{12}\text{H}_8\text{N.COCH}_3$                      | 209.17          | $\text{C}_{14}\text{H}_{11}\text{ON}$            |
| 8 — chloride                          | $\text{CH}_3\text{CO.Cl}$                                     | 78.49           | $\text{C}_2\text{H}_3\text{OCl}$                 |
| 9 — disulphide                        | $(\text{CH}_3\text{CO})_2\text{S}$                            | 160.19          | $\text{C}_4\text{H}_6\text{O}_2\text{S}_2$       |
| 10 — glycine                          | $\text{CH}_3\text{CO.NH.CH}_2\text{COOH}$                     | 117.09          | $\text{C}_4\text{H}_7\text{O}_3\text{N}$         |
| 11 — hydroxy benzoic acid             | $\text{CH}_3\text{CO.C}_6\text{H}_3(\text{OH})\text{COOH}$    | 180.11          | $\text{C}_9\text{H}_8\text{O}_4$                 |
| 12 — indole, 3                        | $\text{CH}_3\text{CO.C}_8\text{H}_5\text{NH}$                 | 159.13          | $\text{C}_{10}\text{H}_9\text{ON}$               |
| 13 ———, 1                             | " "   | 159.13          | " "  |
| 14 — iodide                           | $\text{CH}_3\text{CO.I}$                                      | 169.15          | $\text{C}_2\text{H}_3\text{OI}$                  |
| 15 — isatin                           | $\text{C}_8\text{H}_4:(\text{CO})_2:\text{N.COCH}_3$          | 189.12          | $\text{C}_{10}\text{H}_7\text{O}_3\text{N}$      |
| 16 — malonic ester                    | $\text{CH}_3\text{CO.CH}:(\text{COOC}_2\text{H}_5)_2$         | 202.56          | $\text{C}_{11}\text{H}_{14}\text{O}_5$           |
| 17 — methyl urée                      | $\text{CH}_3\text{NH.CO.NH.COCH}_3$                           | 116.10          | $\text{C}_4\text{H}_8\text{O}_2\text{N}_2$       |
| 18 — naphthol, $\alpha$               | $\text{C}_{10}\text{H}_7\text{O.COCH}_3$                      | 186.14          | $\text{C}_{12}\text{H}_{10}\text{O}_2$           |
| 19 ———, $\beta$                       | " "   | 186.14          | " "  |
| 20 — oxamic ester                     | $\text{CH}_3\text{CO.NH.CO.COOC}_2\text{H}_5$                 | 159.11          | $\text{C}_8\text{H}_9\text{O}_4\text{N}$         |
| 21 — peroxide                         | $(\text{CH}_3\text{CO})_2\text{O}_2$                          | 118.07          | $\text{C}_4\text{H}_6\text{O}_4$                 |
| 22 — phenol                           | $\text{C}_6\text{H}_5\text{O.COCH}_3$                         | 136.10          | $\text{C}_8\text{H}_5\text{O}_2$                 |
| 23 — <i>p</i> -phenylene diamine      | $\text{NH}_2\text{C}_6\text{H}_4\text{NH.COCH}_3$             | 150.14          | $\text{C}_8\text{H}_{10}\text{ON}$               |
| 24 — phenyl hydrazine                 | $\text{C}_6\text{H}_5\text{NH.NH.COCH}_3$                     | 150.14          | $\text{C}_8\text{H}_{10}\text{ON}_2$             |
| 25 — propionic acid                   | $\text{CH}_3\text{CO.C}_2\text{H}_4\text{COOH}$               | 116.09          | $\text{C}_5\text{H}_8\text{O}_3$                 |
| 26 — pyrrole                          | $\text{C}_4\text{H}_5\text{N.COCH}_3$                         | 109.10          | $\text{C}_6\text{H}_7\text{ON}$                  |
| 27 — quinine                          | $\text{C}_{20}\text{H}_{23}\text{O}_2\text{N}_2\text{COCH}_3$ | 336.34          | $\text{C}_{22}\text{H}_{26}\text{O}_3\text{N}_2$ |
| 28 — salicylic acid                   | $\text{COOH.C}_6\text{H}_4\text{O.COCH}_3$                    | 180.11          | $\text{C}_9\text{H}_8\text{O}_4$                 |
| 29 — succinic ester                   | $\text{CH}_3\text{CO.CH}(\text{COOC}_2\text{H}_5)_2$          | 216.18          | $\text{C}_{10}\text{H}_{16}\text{O}_5$           |
| 30 — thiocyanate                      | $\text{CH}_3\text{CO.SCN}$                                    | 105.17          | $\text{C}_3\text{H}_3\text{ONS}$                 |
| 31 — thio-urea                        | $\text{NH}_2\text{CS.NH.COCH}_3$                              | 118.14          | $\text{C}_3\text{H}_5\text{ON}_2\text{S}$        |
| 32 — urea                             | $\text{NH}_2\text{CO.NH.COCH}_3$                              | 102.08          | $\text{C}_3\text{H}_6\text{O}_2\text{N}_2$       |
| 33 Acetylene                          | $\text{H}:\text{CH}$  | 26.03           | $\text{C}_2\text{H}_2$                           |
| 34 — dicarboxylic acid                | $\text{JOOH.C}:\text{C.COOH}$                                 | 114.04          | $\text{C}_4\text{H}_2\text{O}_4$                 |
| 35 — dichloride, see                  | Dichlor ethylene  |                 |  |
| 36 — tetrachloride, see               | Tetra chlor ethane  |                 |  |

| Density<br>H <sub>2</sub> O=1. | Solubility in |          |                                  | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|---------------|----------|----------------------------------|-------------|-------------|----|
|                                | Water.        | Alcohol. | Ether.                           |             |             |    |
|                                | o.s.s.        | h.s.     | s.s.                             | 248         | subl.       | 1  |
|                                | s.s.          | s.       | s.s.                             | 253—254     |             | 2  |
|                                | h.v.s.        | v.s.     |                                  | 201         |             | 3  |
|                                | h.s.          |          |                                  | 114—115     |             | 4  |
|                                | s.s.          | s.s.     | s.s.                             | 205         | subl.       | 5  |
|                                |               |          |                                  |             | 81          | 6  |
|                                | s.s.          | v.s.     | v.s.                             | 69          | >360        | 7  |
| 1.1051/20°                     | d             |          | liq.                             |             | 51—52/720   | 8  |
|                                | i.            | s.       | s. CS <sub>2</sub>               | 20          | d.          | 9  |
|                                | 2.7 : 100/15° | s.       | i.                               | d. 130      |             | 10 |
|                                | h.s.          | s.       | s.                               | 129         |             | 11 |
|                                | s.            |          |                                  | 189         | subl.       | 12 |
| 1.98/17°                       | d.            |          |                                  | liq.        | 152—153/14  | 13 |
|                                | s.s.          | s.       | s. C <sub>6</sub> H <sub>6</sub> | 200—201     | 108         | 14 |
| 1.080/23°                      |               | s.       |                                  | liq.        | 238—240     | 15 |
|                                | h.s.s         | s.s.     | s.s.                             | 180—181     |             | 16 |
| 1.1336/0°                      |               | v.s.     | v.s.                             | 46          | 296         | 17 |
|                                |               |          |                                  | 70          |             | 18 |
|                                | i.            | s.       | s.                               | 52—54       |             | 19 |
|                                |               |          |                                  | 30          | 63/21mm.    | 20 |
| 1.0927/0°                      |               |          |                                  |             | 193         | 21 |
|                                | o.v.s., h.s.  | s.s.     | s.s.                             | 162—162.5   |             | 22 |
|                                |               |          |                                  |             |             | 23 |
|                                | s.s.          | s.       | s.s.                             | 128         |             | 24 |
| 1.135/15°                      | v.s.          | v.s.     | v.s.                             | 33          | 239         | 25 |
|                                | s.s.          | s.       | s.                               | 90          | 218         | 26 |
|                                |               | v.s.     | v.s.                             | 108         |             | 27 |
|                                | 1 : 945       | s.       | s.                               | 135         |             | 28 |
| 1.079/<br>18—21°               | i.            | s.       |                                  | liq.        | 254—256     | 29 |
| 1.151/16°                      | d.            |          |                                  |             | 132—133     | 30 |
|                                | h.s.          | s.       | s.s.                             | 165         |             | 31 |
|                                |               | s.       | h.s.                             | 214         |             | 32 |
|                                | 1 : 1         | 6 : 1    |                                  | — 81.5      |             | 33 |
|                                | v.s.          | v.s.     | v.s.                             | 178—179     |             | 34 |
|                                |               |          |                                  |             |             | 35 |
|                                |               |          |                                  |             |             | 36 |

| Name.   | Formula.  | Formula Weight. | Empirical Formula.   |
|---|---|-----------------|----------------------|
| 1 Acetylene tetrabromide, see Tetra brom ethane |   |                 |                      |
| 2 — urea  | $C_2H_2(CON_2H_2)_2$  | 142.11          | $C_4H_6O_2N_4$       |
| 3 Achroodextrine                                | $C_{36}H_{62}O_{31}$  | 990.68          | $C_{36}H_{62}O_{31}$ |
| 4 Aconic acid                                   | $(OH)CH:C(COOH).CH_2.COOH$  | 146.05          | $C_8H_6O_5$          |
| 5 Aconine                                       | $C_{25}H_{41}NO_9$  | 499.46          | $C_{25}H_{41}O_9N$   |
| 6 Aconitic acid                                 | $C_3H_3(COOH)_3$  | 174.08          | $C_6H_6O_6$          |
| 7 Acridine                                      |    | 179.15          | $C_{13}H_9N$         |
| 8 Acridone                                      |    | 195.14          | $C_{13}H_9ON$        |
| 9 Acrolein                                      | $CH_2:OH.CHO$   | 56.05           | $C_2H_2O$            |
| 10 Acrylic acid                                 | $CH_2:CH.COOH$  | 72.05           | $C_3H_4O_2$          |
| 11 Adenine, see Amino-purine                    |   |                 |                      |
| 12 Adipic acid                                  | $COOH.(CH_2)_4.COOH$  | 146.11          | $C_6H_{10}O_4$       |
| 13 Adipinketone, see Cyclopentanone             |   |                 |                      |
| 14 Æsculetin                                    | $C_9H_8O_4.H_2O$  | 196.11          | $C_9H_8O_4$          |
| 15 Æsculin                                      | $2C_{15}H_{16}O_9.3H_2O$  | 734.46          | $C_{15}H_{16}O_9$    |
| 16 Alanine, <i>α</i>                            | $CH_3.CH(NH_2)COOH$   | 89.08           | $C_3H_7O_2N$         |
| 17 Aldehyde ammonia,                            | see Acetaldehyde ammonia  |                 |                      |
| 18 Aldehydin                                    | $CH_3.C_5H_3N(C_2H_5)$  | 120.13          | $C_8H_{10}N$         |
| 19 Aldehydo-benzoic acid, <i>o</i>              | $COOH.C_6H_4.CHO$   | 150.09          | $C_8H_6O_3$          |
| 20 ———, <i>m</i>                                | „ „   | 150.09          | „                    |
| 21 ———, <i>p</i>                                | „ „   | 150.09          | „                    |
| 22 — hydroxy-benzoic acid, 3:4:1                | $COOH.C_6H_3OH.CHO$   | 166.09          | $C_8H_6O_4$          |
| 23 ———, 4:3:1                                   | „ „   | 166.09          | „                    |
| 24 ———, 3:2:1                                   | „ „   | 166.09          | „                    |
| 25 ———, 2:5:1                                   | „ „   | 166.09          | „                    |
| 26 Aldol  | $CH_3.CHOH.CH_2.CHO$  | 88.08           | $C_4H_8O_2$          |
| 27 Alizarin, see Dihydroxy anthraquinone        |   |                 |                      |
| 28 — amide, <i>o</i>                            | $C_6H_4:(CO)_2:C_6H_2(OH)NH_2$  | 239.15          | $C_{14}H_9O_3N$      |
| 29 — carboxylic acid, 8                         | $COOH.C_6H_3:(CO)_2:C_6H_2:(OH)_2$  | 284.14          | $C_{15}H_8O_6$       |
| 30 — sulphonic acid                             | $C_{14}H_7O_4(SO_3H)$   | 320.19          | $C_{14}H_8O_7S$      |
| 31 Allantoin                                    |  | 158.11          | $C_4H_6O_3N$         |

| Density<br>H <sub>2</sub> O=1.  | Solubility in                 |               |           | M.P.<br>°C. | B.P.<br>°C. |    |
|---------------------------------|-------------------------------|---------------|-----------|-------------|-------------|----|
|                                 | Water                         | Alcohol.      | Ether.    |             |             |    |
| <H <sub>2</sub> O<br>1.0621/16° | 1 : 1075/17°                  | s.            | s. ac.    |             | 900 d.      | 1  |
|                                 | s.                            | i.            |           |             |             | 2  |
|                                 | 1 : 5.6                       |               | s.s.      | 164         |             | 3  |
|                                 | v.s.                          | v.s.          | i.        | 130         |             | 4  |
|                                 | 18 : 100                      | 1 : 2         | v.s.      | 191         |             | 5  |
|                                 |                               |               |           |             |             | 6  |
|                                 | h.s.s.                        | s.            | s.        | 107         | >360        | 7  |
|                                 |                               |               |           |             |             |    |
|                                 |                               | h.s.s.        | i.        | 354 (corr.) |             | 8  |
|                                 | 1 : 2.5                       | s.            | s.        | liq.        | 50          | 9  |
|                                 | m.                            |               |           | 10.1—10.3   | 140         | 10 |
| 1.1094/16°                      | 1.44 : 100                    | v.s.          | 605 : 100 | 149         | 265/100mm   | 11 |
|                                 |                               |               |           |             |             | 12 |
|                                 | c.s.s.                        | s.            | s. alk.   | d. 270      |             | 13 |
|                                 | 1 : 670/10°                   | h. 1 : 24     | i.        | an. 160 d.  |             | 14 |
|                                 | 1 : 4.6/17°                   | 1 : 500(80%)c |           | 283—284 d.  |             | 15 |
|                                 |                               |               |           |             |             | 16 |
|                                 | i.                            | s.            | s.        |             | 180         | 17 |
|                                 |                               |               |           | 97          |             | 18 |
|                                 |                               |               |           |             |             | 19 |
|                                 |                               |               |           | 175         |             | 20 |
|                                 | s.s.                          | v.s.          | s.s.      | 246         |             | 21 |
|                                 | h.s.s.                        | s.            | s.        | 234         |             | 22 |
|                                 |                               |               |           |             |             |    |
|                                 | h.s.                          | s.            | s.        | 243—244     | subl        | 23 |
|                                 | 1 : 15/100°                   | s.            |           | 179         |             | 24 |
|                                 | 1 : 150/100°                  | h.s.          | s.        | 248—249     |             | 25 |
|                                 | m.                            | m.            | s.        | syrup       | 83/20mm     | 26 |
|                                 |                               |               |           |             |             | 27 |
|                                 | i.                            | s.            | s.        | 225         | subl. 150   | 28 |
|                                 | v.s.s.                        | s.            | s.s.      | 321—322     | subl.       | 29 |
|                                 |                               |               |           |             |             |    |
|                                 | s.                            | s.            | i.        |             |             | 30 |
|                                 |                               |               |           |             |             |    |
|                                 | c. 0.6 : 100,<br>h. 3.3 : 100 | s.s.          | i.        | 232—233     |             | 31 |

| Name.                                     | Formula.   | Formula Weight. | Empirical Formula.                               |
|---|--|-----------------|--|
| 1 Allanturic acid                         | $\text{NH}_2 \cdot \text{CO} \cdot \text{NH} \cdot \text{CO} \cdot \text{COOH}$  | 132.07          | $\text{C}_4\text{H}_4\text{O}_5\text{N}_2$       |
| 2 Allocinnamic acid                       | $\text{C}_9\text{H}_8\text{O}_2$   | 148.11          | $\text{C}_9\text{H}_8\text{O}_2$                 |
| 3 Allophanate, ethyl                      | $\text{NH}_2 \cdot \text{CO} \cdot \text{NH} \cdot \text{COOC}_2\text{H}_5$  | 132.10          | $\text{C}_4\text{H}_8\text{O}_3\text{N}_2$       |
| 4 Alloxan                                 | $\text{CO} \begin{array}{c} \diagup \text{NH} \cdot \text{CO} \diagdown \\ \diagdown \text{NH} \cdot \text{CO} \diagup \end{array} \text{CO}$  | 142.06          | $\text{C}_4\text{H}_2\text{O}_4\text{N}_2$       |
| 5 Alloxanic acid                          | $\text{NH}_2 \cdot \text{CO} \cdot \text{NH} \cdot \text{CO} \cdot \text{CO} \cdot \text{COOH}$  | 160.07          | $\text{C}_4\text{H}_4\text{O}_5\text{N}_2$       |
| 6 Alloxantin                              | $\left[ \text{CO} \begin{array}{c} \diagup \text{NH} \cdot \text{CO} \diagdown \\ \diagdown \text{NH} \cdot \text{CO} \diagup \end{array} \right]_2 \text{C} \begin{array}{c} \diagup \diagdown \\ \diagdown \diagup \end{array} \text{O}$ | 268.11          | $\text{C}_8\text{H}_4\text{O}_7\text{N}_4$       |
| 7 Allyl acetic acid                       | $\text{C}_3\text{H}_5 \cdot \text{CH}_2 \cdot \text{COOH}$   | 100.09          | $\text{C}_5\text{H}_8\text{O}_2$                 |
| 8 — acetone                               | $\text{CH}_3 \cdot \text{CO} \cdot \text{CH}_2 \cdot \text{C}_3\text{H}_5$   | 98.11           | $\text{C}_5\text{H}_{10}\text{O}$                |
| 9 — alcohol                               | $\text{C}_3\text{H}_5\text{OH}$  | 58.06           | $\text{C}_3\text{H}_8\text{O}$                   |
| 10 — amine                                | $\text{C}_3\text{H}_5\text{NH}_2$  | 57.08           | $\text{C}_3\text{H}_7\text{N}$                   |
| 11 — aniline                              | $\text{C}_6\text{H}_5\text{NH}_2 \cdot \text{C}_3\text{H}_5$   | 133.14          | $\text{C}_9\text{H}_{11}\text{N}$                |
| 12 — benzene                              | $\text{C}_6\text{H}_6$   | 118.13          | $\text{C}_6\text{H}_6$                           |
| 13 — bromide                              | $\text{C}_3\text{H}_5\text{Br}$  | 120.98          | $\text{C}_3\text{H}_5\text{Br}$                  |
| 14 — chloride                             | $\text{C}_3\text{H}_5\text{Cl}$  | 76.52           | $\text{C}_3\text{H}_5\text{Cl}$                  |
| 15 — cyanide                              | $\text{C}_3\text{H}_5\text{CN}$  | 67.07           | $\text{C}_3\text{H}_5\text{N}$                   |
| 16 — ether                                | $(\text{C}_3\text{H}_5)_2\text{O}$   | 98.11           | $\text{C}_6\text{H}_{10}\text{O}$                |
| 17 — ethyl ether                          | $\text{C}_3\text{H}_5 \cdot \text{O} \cdot \text{C}_2\text{H}_5$   | 86.11           | $\text{C}_5\text{H}_{10}\text{O}$                |
| 18 — iodide                               | $\text{C}_3\text{H}_5\text{I}$   | 167.98          | $\text{C}_3\text{H}_5\text{I}$                   |
| 19 — isocyanide                           | $\text{C}_3\text{H}_5\text{NC}$  | 67.07           | $\text{C}_3\text{H}_5\text{N}$                   |
| 20 — malonic acid                         | $\text{C}_3\text{H}_5 \cdot \text{CH} : (\text{COOH})_2$   | 144.09          | $\text{C}_4\text{H}_5\text{O}_4$                 |
| 21 — mercaptan                            | $\text{C}_3\text{H}_5\text{SH}$  | 74.12           | $\text{C}_3\text{H}_8\text{S}$                   |
| 22 — phenyl ether                         | $\text{C}_6\text{H}_5 \cdot \text{O} \cdot \text{C}_3\text{H}_5$   | 134.13          | $\text{C}_9\text{H}_{10}\text{O}$                |
| 23 — — urea                               | $\text{C}_6\text{H}_5 \cdot \text{NH} \cdot \text{CO} \cdot \text{NH} \cdot \text{C}_3\text{H}_5$  | 176.16          | $\text{C}_{10}\text{H}_{12}\text{ON}_2$          |
| 24 — pyridine                             | $\text{C}_5\text{H}_5\text{N}$   | 119.12          | $\text{C}_5\text{H}_5\text{N}$                   |
| 25 — sulphide                             | $(\text{C}_3\text{H}_5)_2\text{S}$   | 114.17          | $\text{C}_6\text{H}_{10}\text{S}$                |
| 26 — thiocyanate                          | $\text{C}_3\text{H}_5 \cdot \text{SCN}$  | 99.13           | $\text{C}_3\text{H}_5\text{NS}$                  |
| 27 — <i>iso</i> -thiocyanate              | $\text{C}_3\text{H}_5 \cdot \text{NSC}$  | 99.13           | „  |
| 28 — trisulphide                          | $(\text{C}_3\text{H}_5)_2\text{S}_3$   | 174.26          | $\text{C}_6\text{H}_{10}\text{S}_3$              |
| 29 Allylene                               | $\text{CH}_2 \cdot \text{C} : \text{CH}$   | 40.05           | $\text{C}_3\text{H}_4$                           |
| 30 — dichloride                           | $\text{CH}_2 \cdot \text{CCl} : \text{CHCl}$   | 110.97          | $\text{C}_3\text{H}_4\text{Cl}_2$                |
| 31 Aluminium ethyl                        | $\text{Al}(\text{C}_2\text{H}_5)_3$  | 114.15          | $\text{C}_6\text{H}_{15}\text{Al}$               |
| 32 — methyl                               | $\text{Al}(\text{CH}_3)_3$   | 72.09           | $\text{C}_3\text{H}_9\text{Al}$                  |
| 33 Amalic acid (tetra-methyl alloxantine) | $(\text{CH}_3)_4\text{C}_8\text{N}_4\text{O}_7$  | 324.20          | $\text{C}_{12}\text{H}_{12}\text{O}_7\text{N}_4$ |
| 34 Amino acetal                           | $\text{NH}_2 \cdot \text{CH}_2 \cdot \text{CH}(\text{OC}_2\text{H}_5)_2$   | 133.16          | $\text{C}_6\text{H}_{15}\text{O}_2\text{N}$      |



| Density<br>H <sub>2</sub> O=1. | Solubility in |          |        | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|---------------|----------|--------|-------------|-------------|----|
|                                | Water.        | Alcohol. | Ether. |             |             |    |
|                                | del.          | i.       |        |             |             | 1  |
| 0.845 :                        |               |          |        | 68          |             | 2  |
| h.s.                           |               | s.s.     |        | 191         | d.          | 3  |
| 100/25°                        |               |          |        |             |             |    |
| s.                             | s.            |          |        |             | 170         | 4  |
| s.                             | 1 : 5         | s.s.     |        | d.          |             | 5  |
| v.s.s.                         | v.s.s.        | v.s.s.   |        |             |             | 6  |
| 0.9842/15°                     | s.s.          | s.       | s.     | liq.        | 182         | 7  |
| 0.832/27°                      | i.            |          |        | liq.        | 239—241/759 | 8  |
| 0.857/15°                      | m.            | s.       |        | liq.        | 96.6/753mm. | 9  |
| 0.7631/20°                     | m.            | s.       |        | liq.        | 56.5/756mm. | 10 |
| 0.982/19°                      | v.s.s.        | s.       |        | oil.        | 208—209     | 11 |
| 0.918/15°                      |               | s.       |        | liq.        | 155         | 12 |
| 1.461/0°                       | i.            |          |        |             | 70—71/753   | 13 |
| 0.9379/20°                     | i.            | s.       |        | - 136.4     | 44.6        | 14 |
| 0.849/0°                       |               | s.       |        | liq.        | 119         | 15 |
| 0.8046/18°                     | i.            | s.       |        | liq.        | 94.3        | 16 |
|                                |               |          |        | liq.        | 64          | 17 |
| 1.85/12°                       | i.            |          |        | liq.        | 102/734mm.  | 18 |
| 0.794/14°                      | s.s.          | s.       |        | liq.        | 119         | 19 |
|                                | s.            | s.       | s.     | 103—105     | d.          | 20 |
|                                | i.            | h.s.s.   | i.     | liq.        | 90          | 21 |
|                                | i.            |          |        | liq.        | 193         | 22 |
|                                |               |          |        | 115         |             | 23 |
| 0.9595                         | v.s.          | v.s.     | i.     |             | 189—190     | 24 |
| 0.88765/26.8°                  | s.s.          |          |        | liq.        | 140         | 25 |
| 1.071/0°                       | i.            |          |        | liq.        | 180—181     | 26 |
| 1.0057/24.2°                   | s.s.          | s.       | s.     | - 80        | 150.7       | 27 |
| 1.012/15°                      | i.            | i.       | m.     |             | 188         | 28 |
|                                | s. oupram.    |          | s.     | - 110       | - 23.5      | 29 |
| 1.23/27°                       |               |          |        | liq.        | 55          | 30 |
|                                | expl.         |          |        | - 18        | 194         | 31 |
|                                |               |          |        | liq.        | 130         | 32 |
|                                | h.s.s.        | v.s.s.   | s. KOH | 176 d.      |             | 33 |
|                                | v.s.s.        | v.s.s.   | v.s.s. |             | 163         | 34 |

| Name.  | Formula.   | Formula Empirical<br>Weight. Formula.                 |
|--|--|---|
| 1 Amino acetanilide, <i>o</i>  | $\text{NH}_2.\text{C}_6\text{H}_4.\text{NH}.\text{COCH}_3$                                       | 150.14 $\text{C}_8\text{H}_9\text{ON}_2$              |
| 2 —, <i>m</i>  | " "  | 150.14 "  |
| 3 —, <i>p</i>  | " "  | 150.14 "  |
| 4 —acetic acid<br>(glycine)  | $\text{NH}_2.\text{CH}_2.\text{COOH}$  | 75.05 $\text{C}_2\text{H}_5\text{O}_2\text{N}$        |
| 5 —acetophenone, <i>o</i>  | $\text{NH}_2.\text{C}_6\text{H}_4.\text{COCH}_3$   | 135.12 $\text{C}_8\text{H}_9\text{ON}$                |
| 6 —, <i>m</i>  | " "  | 135.12 "  |
| 7 —, <i>p</i>  | " "  | 135.12 "  |
| 8 —anthraquinone, $\alpha$   | $\text{C}_{14}\text{H}_7\text{O}_2.\text{NH}_2$  | 223.15 $\text{C}_{14}\text{H}_9\text{O}_2\text{N}$    |
| 9 —, $\beta$   | " "  | 223.15 "  |
| 10 —azobenzene, <i>p</i>   | $\text{NH}_2.\text{C}_6\text{H}_4.\text{N}_2.\text{C}_6\text{H}_5$                               | 197.18 $\text{C}_{12}\text{H}_{11}\text{N}_3$         |
| 11 —azonaphthalene, $\alpha$   | $\text{C}_{10}\text{H}_7.\text{N}_2.\text{C}_{10}\text{H}_6.\text{NH}_2$                         | 297.25 $\text{C}_{20}\text{H}_{15}\text{N}_3$         |
| 12 —, $\beta$  | " "  | 297.25 "  |
| 13 —azetoluene,<br>$\text{CH}_3:\text{N}:\text{N}:\text{CH}_3:\text{NH}_2$<br>=1:2:5:1:2 | $\text{CH}_3.\text{C}_6\text{H}_4.\text{N}_2.\text{C}_6\text{H}_3(\text{NH}_2)$<br>$\text{CH}_3$ | 225.22 $\text{C}_{14}\text{H}_{15}\text{N}_3$         |
| 14 —, 1:3:5:1:2  | " "  | 225.22 "  |
| 15 —, 1:4:5:1:2  | " "  | 225.22 "  |
| 16 —, 1:4:6:1:3  | " "  | 225.22 "  |
| 17 —benzaldehyde, <i>o</i>   | $\text{NH}_2.\text{C}_6\text{H}_4.\text{CHO}$  | 121.10 $\text{C}_7\text{H}_7\text{ON}$                |
| 18 —, <i>m</i>   | " "  | 121.10 "  |
| 19 —, <i>p</i>   | " "  | 121.10 "  |
| 20 —benzamide, <i>m</i>  | $\text{NH}_2.\text{C}_6\text{H}_4.\text{CONH}_2$   | 136.12 $\text{C}_7\text{H}_7\text{ON}_2$              |
| 21 —, <i>p</i>   | " "  | 136.12 "  |
| 22 —benzene sulphonio<br>acid <i>o</i> , Anthranilic acid                                | $\text{NH}_2.\text{C}_6\text{H}_4.\text{SO}_3\text{H}.\frac{1}{2}\text{H}_2\text{O}$             | 182.17 $\text{C}_6\text{H}_7\text{O}_3\text{NS}$      |
| 23 ———, <i>m</i> ,<br>Sulphanilic acid   | " " $\frac{1}{2}\text{H}_2\text{O}$  | 182.17 "  |
| 24 ———, <i>p</i> ,<br>Metanilic acid   | " " $2\text{H}_2\text{O}$  | 209.19 "  |
| 25 —benzoic acid, <i>o</i>   | $\text{NH}_2.\text{C}_6\text{H}_4.\text{COOH}$   | 137.10 $\text{C}_7\text{H}_7\text{O}_2\text{N}$       |
| 26 ———, <i>m</i>   | " "  | 137.10 "  |
| 27 ———, <i>p</i>   | " "  | 137.10 "  |
| 28 —benzophenone, <i>o</i>   | $\text{C}_6\text{H}_5.\text{CO}.\text{C}_6\text{H}_4.\text{NH}_2$                                | 197.16 $\text{C}_{13}\text{H}_{11}\text{O}_2\text{N}$ |
| 29 —, <i>m</i>   | " "  | 197.16 "  |
| 30 —, <i>p</i>   | " "  | 197.16 "  |
| 31 —butyric acid, $\alpha$   | $\text{C}_2\text{H}_5.\text{CH}(\text{NH}_2).\text{COOH}$  | 103.10 $\text{C}_4\text{H}_9\text{O}_2\text{N}$       |
| 32 ———, $\beta$  | $\text{CH}_3.\text{CH}(\text{NH}_2).\text{CH}_2.\text{COOH}$                                     | 103.10 "  |
| 33 —camphor  | $\text{C}_{10}\text{H}_{15}\text{O}.\text{NH}_2$   | 167.20 $\text{C}_{10}\text{H}_{17}\text{ON}$          |

| Density<br>H <sub>2</sub> O=1. | Water.                            | Solubility in<br>Alcohol. | Ether.                                 | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|-----------------------------------|---------------------------|--|-------------|-------------|----|
|                                | s.s.                              |                           |  | 145         |             | 1  |
|                                |                                   | s.s.                      |  | 70—100 d.   |             | 2  |
|                                | v.s.                              | s.s.                      | s.s.                                   | 162—162.5   |             | 3  |
| 1.1607                         | 23 : 100                          | 0.2 : 100                 |  | 240         | d.          | 4  |
|                                |                                   |                           |  |             | 250—252     | 5  |
|                                |                                   |                           |  | 90          |             | 6  |
|                                | h.s.s.                            | s.s.                      | s.s., s. C <sub>6</sub> H <sub>6</sub> | 110 (corr.) | 293—295     | 7  |
|                                | i.                                | s.s.                      | s.s.                                   | 243         | subl.       | 8  |
|                                | i.                                | s.                        | i.                                     | 302         |             | 9  |
|                                | h.s.s.                            | s.s.                      | s.s.                                   | 127         | 225/120mm.  | 10 |
|                                | s. H <sub>2</sub> SO <sub>4</sub> | s.s.                      | s.s.                                   | 173—175     |             | 11 |
|                                |                                   |                           |  | 159         |             | 12 |
|                                |                                   | s.                        |  | 100         |             | 13 |
|                                | v.s.s.                            | s.                        |  | 80          |             | 14 |
|                                | i.                                | s.                        |  | 127—128     |             | 15 |
|                                |                                   | s.                        |  | 127         |             | 16 |
|                                | s.s.                              | v.s.                      | v.s.                                   | 39—40       | d.          | 17 |
|                                |                                   |                           | v.g.                                   |             |             | 18 |
|                                | s.                                | s.                        |  | 70          |             | 19 |
|                                | s.                                | s.                        |  | 75          |             | 20 |
|                                | s.s.                              | s.                        |  | 179         |             | 21 |
|                                | 1.66 :                            | s                         |  |             |             | 22 |
|                                | 100/11°                           |                           |  |             |             |    |
|                                | 1 : 68/15°                        | s                         |  |             |             | 23 |
|                                | 1 : 166/10°                       |                           |  | 1. 280      |             | 24 |
| 1.412/20°                      | h.s.                              | s.                        | s.                                     | 144.6       | d.          | 25 |
| 1.5105/4°                      | h.s.                              | s.                        | s.                                     | 174.4       |             | 26 |
| 1.393/20°                      | h.s.                              | s.                        | s.                                     | 186         |             | 27 |
|                                |                                   | s.                        | s.                                     | 110—111     |             | 28 |
|                                | s.s.                              | s.                        | s.                                     | 87          |             | 29 |
|                                | h.s.                              | s.                        | s.                                     | 124         |             | 30 |
|                                | 1 : 3.5                           | h. 1 : 550                |  | 303         |             | 31 |
|                                | del. 1 : 1                        | s.                        | i.                                     | 184         |             | 32 |
|                                |                                   | h.s.                      | s. a.c.                                | 226—228 d.  | 246.4       | 33 |

Name.

Formula.

Formula Empirical  
Weight. Formula.

|  |  |        |   |
|--|--|--------|---|
| 1 Amino caproic acid   | $(\text{CH}_3)_2 : \text{CH} \cdot \text{CH}_2 \cdot \text{CH}(\text{NH}_2) \cdot \text{COOH}$ | 131.14 | $\text{C}_6\text{H}_{13}\text{O}_2\text{N}$         |
| 2 — <i>iso</i> -caproic acid   | " "  | 131.14 | " "   |
| 3 — cinnamic acid, <i>o</i>  | $\text{NH}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{O}_2\text{H}_2 \cdot \text{COOH}$          | 163.13 | $\text{C}_9\text{H}_9\text{O}_2\text{N}$            |
| 4 — — —, <i>m</i>  | " "  | 163.13 | " "   |
| 5 — — —, <i>p</i>  | " "  | 163.13 | " "   |
| 6 — <i>p</i> -cresol, 3  | $\text{NH}_2 \cdot \text{C}_6\text{H}_3(\text{OH})\text{CH}_3$                                 | 123.12 | $\text{C}_7\text{H}_9\text{ON}$                     |
| 7 — dimethylaniline, <i>p</i>  | $\text{NH}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{N} : (\text{CH}_3)_2$                      | 136.16 | $\text{C}_8\text{H}_{12}\text{N}_2$                 |
| 8 — diphenyl, <i>o</i>   | $\text{C}_6\text{H}_5 \cdot \text{C}_6\text{H}_4 \cdot \text{NH}_2$                            | 169.16 | $\text{C}_{12}\text{H}_{11}\text{N}$                |
| 9 — — —, <i>p</i>  | " "  | 169.16 | " "   |
| 10 — diphenylamine   | $\text{NH}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{NH} \cdot \text{C}_6\text{H}_5$            | 184.18 | $\text{C}_{12}\text{H}_{12}\text{N}$                |
| 11 — ethyl alcohol   | $\text{NH}_2 \cdot \text{CH}_2 \cdot \text{CH}_2\text{OH}$                                     | 61.07  | $\text{C}_2\text{H}_7\text{ON}$                     |
| 12 — — benzene, <i>o</i>   | $\text{C}_2\text{H}_5 \cdot \text{C}_6\text{H}_4 \cdot \text{NH}_2$                            | 121.14 | $\text{C}_8\text{H}_{11}\text{N}$                   |
| 13 — — —, <i>p</i>   | " "  | 121.14 | " "   |
| 14 — guanidine   | $\text{NH} : \text{C}(\text{NH}_2)\text{NH} \cdot \text{NH}_2$                                 | 74.09  | $\text{CH}_4\text{N}_4$                             |
| 15 — hexahydro benzene   | $\text{NH}_2 \cdot \text{C}_6\text{H}_5(\text{H})$   | 99.14  | $\text{C}_6\text{H}_{13}\text{N}$                   |
| 16 — $\beta$ naphthol, 7   | $\text{NH}_2 \cdot \text{C}_{10}\text{H}_6\text{OH}$   | 159.13 | $\text{C}_{10}\text{H}_9\text{ON}$                  |
| 17 — $\beta$ —, 1  | " "  | 159.13 | " "   |
| 18 — $\alpha$ —, 4   | " "  | 159.13 | " "   |
| 19 — nitro benzoic acid,<br>$\text{COOH} : \text{NH}_2 : \text{NO}_2 =$<br>1 : 2 : 5 | $\text{C}_6\text{H}_3(\text{NH}_2)(\text{NO}_2)\text{COOH}$                                    | 182.10 | $\text{C}_7\text{H}_6\text{O}_4\text{N}_2$          |
| 20 1 : 2 : 3   | " "  | 182.10 | " "   |
| 21 1 : 3 : 6   | " "  | 182.10 | " "   |
| 22 1 : 3 : 2   | " "  | 182.10 | " "   |
| 23 1 : 3 : 5   | " "  | 182.10 | " "   |
| 24 1 : 3 : 4   | " "  | 182.10 | " "   |
| 25 1 : 4 : 3   | " "  | 182.10 | " "   |
| 26 — — chlor phenol,<br>2 : 6 : 4  | $\text{C}_6\text{H}_2\text{OH}(\text{NH}_2)(\text{NO}_2)\text{Cl}$                             | 188.52 | $\text{C}_6\text{H}_5\text{O}_3\text{N}_2\text{Cl}$ |
| 27 — — phenol<br>$\text{NO}_2 : \text{OH} : \text{NH}_2 =$<br>6 : 1 : 2              | $\text{C}_6\text{H}_3\text{OH}(\text{NO}_2)(\text{NH}_2)$                                      | 154.10 | $\text{C}_6\text{H}_6\text{O}_3\text{N}_2$          |
| 28 3 : 1 : 2   | " "  | 154.10 | " "   |
| 29 4 : 1 : 2   | " "  | 154.10 | " "   |
| 30 — phenol, <i>o</i>  | $\text{NH}_2 \cdot \text{C}_6\text{H}_4\text{OH}$  | 109.15 | $\text{C}_6\text{H}_7\text{ON}$                     |
| 31 — —, <i>m</i>   | " "  | 109.15 | " "   |
| 32 — —, <i>p</i>   | " "  | 109.15 | " "   |
| 33 — propionic acid, $\alpha$  | $\text{CH}_3 \cdot \text{CH}(\text{NH}_2)\text{COOH}$  | 89.08  | $\text{C}_3\text{H}_7\text{O}_2\text{N}$            |
| 34 — — —, $\beta$  | $\text{CH}_2(\text{NH}_2)\text{CH}_2 \cdot \text{COOH}$  | 89.08  | " "   |

| Density<br>H <sub>2</sub> O=1. | Water.    | Solubility in |   | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|-----------|---------------|---|-------------|-------------|----|
|                                |           | Alcohol.      | Ether.  |             |             |    |
| 1.293                          | 1: 46/18° | h.s.s.        |   | 170         | d.          | 1  |
|                                | 1: 117.5  | s.s.          |   | 214—215     |             | 2  |
|                                | h.s.      | s.            | s.  | 158         |             | 3  |
|                                | h.s.      | s.            | s.  | 180         |             | 4  |
|                                | h.s.      | s.            | s.  | 175—176     |             | 5  |
|                                | i.        | s.            | s.  | 135         |             | 6  |
| 1.0414/15°                     | s.        | v.s.          | v.s.  | 41          | 262.3       | 7  |
|                                | i.        | s.            |   | 45.5        | 299         | 8  |
|                                | h.s.      | s.s.          | s.  | 53          | 302         | 9  |
|                                | s.s.      | s.            | s.  | 75          | 354         | 10 |
| 1.022/0°                       | m.        | m.            |   |             | 171/757mm   | 11 |
| 0.983/22°                      |           |               |   | liq.        | 210—211     | 12 |
| 0.975/22°                      | s.s.      |               | s.dil.H <sub>2</sub> SO <sub>4</sub>                    | liq.        | 213—214     | 13 |
|                                | s.s.      | s.s.          | i.  |             |             | 14 |
|                                |           |               |   |             | 134         | 15 |
|                                | s.s.      | s.            | s.  | 201         |             | 16 |
|                                | h.s.s.    |               | s. fluoresc.  |             |             | 17 |
|                                | s.d.      |               |   |             |             | 18 |
|                                | h.s.      | s.            | s.  | 263 d.      |             | 19 |
|                                |           |               |   |             |             |    |
|                                | h.s.      | v.s.          | v.s.  | 204         |             | 20 |
|                                | h.s.s.    | h.s.          |   | 235 d.      |             | 21 |
|                                | h.v.s.    | v.s.          | v.s.  | 156—157     |             | 22 |
|                                | s.s.      | h.s.          | v.s.  | 208         |             | 23 |
|                                | s.s.      | v.s.          | s.  | 298         |             | 24 |
|                                | i.        | h.s.s.        |   | 277—278     |             | 25 |
|                                |           |               |   | 152         |             | 26 |
|                                |           |               |   |             |             |    |
|                                | h.v.s.    | s             | s. CHCl <sub>3</sub> ,<br>C <sub>6</sub> H <sub>6</sub> | 110—111     |             | 27 |
|                                |           |               |   |             |             |    |
|                                | h.s.      | s.            | s.  | 76          |             | 28 |
|                                | h.s.      | v.s.          | v.s.  | 89—90       |             | 29 |
|                                | 1: 59/0°  | 1: 23         | s.s.  | 170         | subl.       | 30 |
|                                | h.s.      | s.            | s.  | 122—123     | subl.       | 31 |
|                                | 1: 90/0°  | 1: 22/0°      |   | 184         |             | 32 |
|                                | h.v.s.    | 0.2: 100      | i.  | subl. 200   | d. 285      | 33 |
|                                | v.s.      | s.s.          |   | 205—206     |             | 34 |

| Name.  | Formula.                         | Formula Empirical |                       |
|--|----------------------------------|-------------------|-----------------------|
|  |                                  | Weight.           | Formula.              |
| 1 Amino purine, $\alpha$<br>(adenine)          | $C_5N_5H_5$                      | 135.12            | $C_5H_5N_5$           |
| 2 — quinoline, $\alpha$                        | $C_9H_6N(NH_2)$                  | 144.13            | $C_9H_8N_2$           |
| 3 — —, $\beta$                                 | " "                              | 144.13            | " "                   |
| 4 — salicylic acid, 1:2:5                      | $NH_2.C_6H_3(OH)COOH$            | 153.10            | $C_7H_7O_3N$          |
| 5 — thiazole                                   | $C_3H_2NS.NH_2$                  | 100.13            | $C_3H_4N_2S$          |
| 6 — thiophen                                   | $C_4H_3S.NH_2$                   | 99.13             | $C_4H_5NS$            |
| 7 — thiophenol, $\alpha$                       | $NH_2.C_6H_4.SH$                 | 125.16            | $C_6H_7NS$            |
| 8 — triphenyl methane                          | $CH(C_6H_5)_3.OH.NH_2$           | 259.24            | $C_{19}H_{17}N$       |
| 9 — succinamic acid                            | $C_4H_3(NH_2)(COOH)CONH_2$       | 132.10            | $C_4H_5O_3N_2$        |
| 10 — succinic acid                             | $C_4H_3(NH_2)(COOH)_2$           | 133.09            | $C_4H_5O_4N$          |
| 11 — valeric acid, $\alpha$                    | $CH_3.CH_2.CH_2.CH(NH_2).COOH$   | 117.12            | $C_5H_{11}O_2N$       |
| 12 — — —, $\gamma$                             | $CH_3.CH(NH_2).CH_2.CH_2.COOH$   | 117.12            | " "                   |
| 13 — — —, $\delta$                             | $NH_2.CH_2.CH_2.CH_2.CH_2.COOH$  | 117.12            | " "                   |
| 14 — <i>iso</i> -valeric acid, $\beta$         | $(CH_3)_2:C(NH_2)CH_2.COOH$      | 117.12            | " "                   |
| 15 — — — —, $\alpha$                           | $(CH_3)_2:CH.CH(NH_2)COOH$       | 117.12            | " "                   |
| 16 Ammelide                                    | $(CN)_3NH_2(OH)_2$               | 128.09            | $C_3H_4O_2N_4$        |
| 17 Ammeline                                    | $(CN)_3(NH_2)_2OH$               | 127.11            | $C_3H_5ON_5$          |
| 18 Amygdalic acid                              | $C_6H_5.CH(COOH).O$              | 627.42            | $C_{28}H_{35}O_{16}$  |
| 19 Amygdalin                                   | $C_6H_5.CH(CN).O.O$<br>$(3H_2O)$ | 457.33            | $C_{20}H_{27}O_{11}N$ |
| 20 Amyl alcohol, <i>norm.</i>                  | $C_5H_{11}.CH_2OH$               | 88.12             | $C_5H_{12}O$          |
| 21 — —, <i>iso</i>                             | $(CH_3)_2:CH.CH_2.CH_2OH$        | 88.12             | $C_5H_{12}O$          |
| 22 — —, diethyl carbinol                       | $(C_2H_5)_2.CHOH$                | 88.12             | " "                   |
| 23 — —, methyl propyl<br>carbinol              | $C_2H_5.CH_2.CHOH.CH_3$          | 88.12             | " "                   |
| 24 — —, methyl <i>iso</i> .<br>propyl carbinol | $(CH_3)_3:CH.CHOH.CH_3$          | 88.12             | " "                   |
| 25 — —, amylene hydrate                        | $(CH_3)_2:C(OH).C_3H_5$          | 88.12             | " "                   |
| 26 — —, <i>tert.</i> butyl<br>carbinol         | $(CH_3)_3C.CH_2OH$               | 88.12             | " "                   |
| 27 — amine, <i>iso</i> .                       | $C_5H_{11}.NH_2$                 | 87.14             | $C_5H_{13}N$          |
| 28 — aniline, <i>iso</i>                       | $C_6H_5.NH.C_5H_{11}$            | 163.20            | $C_{11}H_{17}N$       |
| 29 — benzene                                   | $C_6H_5.C_5H_{11}$               | 148.18            | $C_{11}H_{16}$        |
| 30 — bromide                                   | $C_5H_{11}Br$                    | 151.03            | $C_5H_{11}Br$         |
| 31 — —, <i>iso</i> .                           | $(CH_3)_2:CH.CH_2.CH_2Br$        | 151.03            | " "                   |
| 32 — carbylamine                               | $C_5H_{11}.NC$                   | 97.13             | $C_5H_{11}N$          |

| Density<br>$H_2O=1$ . | Solubility in |          |        | M.P.<br>°C. | B.P.<br>°C.     |    |
|-----------------------|---------------|----------|--------|-------------|-----------------|----|
|                       | Water.        | Alcohol. | Ether. |             |                 |    |
|                       | h.s.          | h.s.     | i.     | d. 360—365  |                 | 1  |
|                       | h.s.          | h.s.     | s.     | 125         |                 | 2  |
|                       | s.            | s.       | s. ac. | 154         |                 | 3  |
|                       | s.s.          | i.       |        | d. 280      |                 | 4  |
|                       | s.s.          | s.s.     | s.s.   | 90          |                 | 5  |
|                       | v.s.          | v.s.     | i.     |             |                 | 6  |
|                       |               |          |        | 26          | 234             | 7  |
|                       |               |          | s.s.   | 83—84       |                 | 8  |
| 1.519/14°             | s.s.          | i.       | i.     | d.          |                 | 9  |
| 1.6613                | 1: 222/20°    | i.       | s.     | 270—271     |                 | 10 |
|                       | s.            | s.s.     | i.     | 291.5 d.    |                 | 11 |
|                       |               |          |        |             |                 |    |
|                       | v.s.          | s.s.     | i.     | 193         | d.              | 12 |
|                       | v.s.          | s.s.     | i.     | 157—158     | d.              | 13 |
|                       |               |          |        |             |                 |    |
|                       | v.s.          | s.s.     | i.     | 217         | subl. 180       | 14 |
|                       | s.            | i.       | i.     | 298 d.      |                 | 15 |
|                       | h. v.s.s.     | i.       | s. ac. |             |                 | 16 |
|                       | i.            | i.       | s. KOH | d.          |                 | 17 |
|                       | del.          | i.       | i.     |             |                 | 18 |
|                       |               |          |        |             |                 |    |
|                       | 8: 100/10°    | h.s.     | i.     | 215 an.     |                 | 19 |
|                       |               |          |        |             |                 |    |
| 0.8121/20°            | i.            |          |        | - 134       | 137.5           | 20 |
| 0.825/0°              | 1: 39         | s.       | s.     | - 134       | 131.6           | 21 |
| 0.816/18°             | i.            | s.       |        | 112—113.5   | 116.3/753mm.    | 22 |
| 0.824/0°              | 1: 6          |          |        | liq.        | 118.5/753mm.    | 23 |
|                       |               |          |        |             |                 |    |
| 0.819/0°              | i.            |          |        | liq.        | 112.5           | 24 |
|                       |               |          |        |             |                 |    |
| 0.814/15°             | s.s.          | s.       |        | - 12        | 101.88          | 25 |
| 0.812/20°             |               |          |        | 53          | 112             | 26 |
|                       |               |          |        |             |                 |    |
| 0.7503/18°            |               | s.       |        | liq.        | 95              | 27 |
| 0.928/15°             |               |          |        | liq.        | 259—262         | 28 |
| 0.8602/22°            |               | s.       |        |             | 200.5—201.5/743 | 29 |
| 1.246/0°              |               | s.       |        | liq.        | 129—130/750     | 30 |
| 1.2358/22°            | i.            | s.       |        | liq.        | 120.5—120.8     | 31 |
| < $H_2O$              | i.            | s.       |        | liq.        | 137             | 32 |

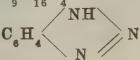
| Name.                          | Formula.                             | Formula Weight. | Empirical Formula.   |
|--------------------------------|--------------------------------------|-----------------|----------------------|
| 1 Amyl chloride                | $C_5H_{11}Cl$                        | 106.57          | $C_5H_{11}Cl$        |
| 2 —, <i>iso</i> .              | $(CH_3)_2:CH.CH_2.CH_2Cl$            | 106.57          | "                    |
| 3 — cyanide                    | $C_5H_{11}CN$                        | 97.13           | $C_5H_{11}N$         |
| 4 — ether, <i>iso</i> .        | $(C_5H_{11})_2O$                     | 155.23          | $C_{10}H_{22}O$      |
| 5 — ethyl aniline              | $C_6H_5.N(C_2H_5)(C_5H_{11})$        | 191.24          | $C_{13}H_{21}N$      |
| 6 — ketone, <i>iso</i> .       | $C_5H_5.CO.C_5H_{11}$                | 128.17          | $C_8H_{16}O$         |
| 7 — iodide                     | $C_5H_{11}I$                         | 198.13          | $C_5H_{11}I$         |
| 8 —, <i>iso</i> .              | $(CH_3)_2:CH.CH_2.CH_2I$             | 198.13          | "                    |
| 9 — mercaptan                  | $C_5H_{11}SH$                        | 104.14          | $C_5H_{12}S$         |
| 10 — methyl benzene, 1:4       | $C_5H_{11}.C_6H_4.CH_3$              | 162.20          | $C_{12}H_{18}$       |
| 11 — ether                     | $C_5H_{11}.O.CH_3$                   | 102.14          | $C_6H_{14}O$         |
| 12 — nitrate, <i>iso</i> .     | $C_5H_{11}.O.NO_2$                   | 133.12          | $C_5H_{11}O_3N$      |
| 13 — nitrite, <i>iso</i> .     | $C_5H_{11}.O.NO$                     | 117.12          | $C_5H_{11}O_2N$      |
| 14 — phenol, <i>iso</i> ., 1:4 | $C_5H_{11}.C_6H_4.OH$                | 164.18          | $C_{11}H_{16}O$      |
| 15 — sulphide                  | $(C_5H_{11})_2S$                     | 174.29          | $C_{10}H_{22}S$      |
| 16 — thiocyanate, <i>iso</i> . | $C_5H_{11}.NCS$                      | 129.19          | $C_5H_{11}NS$        |
| 17 — urethane                  | $C_5H_{11}.O.CONH_2$                 | 131.14          | $C_6H_{13}O_2N$      |
| 18 Amylene, ethyl propylene    | $CH_3.CH_2.CH:CH.CH_3$               | 70.11           | $C_5H_{10}$          |
| 19 —, trimethylethylene        | $(CH_3)_2:C:CH.CH_3$                 | 70.11           | "                    |
| 20 —, <i>iso</i> .             | $(CH_3)_2:CH.CH:CH_2$                | 70.11           | "                    |
| 21 — glycol                    | $C_5H_{10}:O(OH)_2$                  | 104.12          | $C_5H_{12}O_2$       |
| 22 Amyloid                     | $(C_5H_{10}O)_x$                     | (162.11)        |                      |
| 23 Analgene                    | $C_7H_5O.NH.C_6H_2(OC_2H_5):C_5H_3N$ | 292.24          | $C_{18}H_{16}O_2N_2$ |
| 24 Anethole, 1:4               | $CH_3.CH:CH.C_6H_4.OCH_3$            | 148.15          | $C_{10}H_{12}O$      |
| 25 Angelic acid                | $C_4H_7.COOH$                        | 100.09          | $C_5H_8O_2$          |
| 26 Anhydroformaldehyde aniline | $C_6H_5.N:CH_2$                      | 105.01          | $C_7H_7N$            |
| 27 Aniline                     | $C_6H_5.NH_2$                        | 93.10           | $C_6H_7N$            |
| 28 — hydrochloride             | $C_6H_5.NH.HCl$                      | 128.55          | $C_6H_7NCl$          |
| 29 Anisalcohol, <i>p</i>       | $CH_3O.C_6H_4.CH_2OH$                | 138.12          | $C_8H_{10}O_2$       |
| 30 Anisaldehyde, <i>p</i>      | $CH_3O.C_6H_4.CH_2O$                 | 136.10          | $C_8H_8O_2$          |
| 31 Anisic acid                 | $CH_3O.C_6H_4.COOH$                  | 152.10          | $C_8H_8O_3$          |
| 32 Anisidine, <i>o</i>         | $CH_3O.C_6H_4.NH_2$                  | 123.12          | $C_7H_9ON$           |
| 33 —, <i>m</i>                 | " "                                  | 123.12          | "                    |
| 34 —, <i>p</i>                 | " "                                  | 123.12          | "                    |
| 35 Anisil, <i>p</i>            | $CH_3O.C_6H_4.CO.CO.C_6H_4.OCH_3$    | 270.19          | $C_{16}H_{14}O_4$    |
| 36 Anisole                     | $C_6H_5.OCH_3$                       | 108.10          | $C_7H_8O$            |



| Density<br>H <sub>2</sub> O=1. | Solubility in— |          |                      | M.P.<br>°C. | B.P.<br>°C.  |    |
|--------------------------------|----------------|----------|----------------------|-------------|--------------|----|
|                                | Water.         | Alcohol. | Ether.               |             |              |    |
| 0.9013/0°                      |                | s.       |                      | liq.        | 106          | 1  |
| 0.875/15°                      | i.             | s.       |                      | liq.        | 100.9        | 2  |
| 0.866/20°                      | s.s.           | s.       | s.                   | liq.        | 144—146      | 3  |
| 0.7807/15°                     | i.             |          |                      | liq.        | 173          | 4  |
|                                |                |          |                      | liq.        | 262          | 5  |
| 0.8502/0°                      |                |          |                      |             | 164—165      | 6  |
| 1.5435/0°                      |                | s.       |                      | liq.        | 156          | 7  |
| 1.468/0°                       |                | s.       |                      | liq.        | 147          | 8  |
| 0.8548/0°                      |                |          |                      | liq.        | 116          | 9  |
| 0.8643/0°                      |                |          |                      | liq.        | 213          | 10 |
| 0.7807/15°                     |                |          |                      | liq.        | 92           | 11 |
| 1.000/7.5°                     |                |          |                      | liq.        | 147—148      | 12 |
| 0.902                          | h.s.s.         | s.       | s.                   |             | 97—98        | 13 |
|                                | h. v.s.s.      |          |                      | 93          | 265—267      | 14 |
| 0.843/20°                      |                | s.s.     | s: CHCl <sub>3</sub> | liq.        | 213          | 15 |
| 0.9575/0°                      |                |          |                      | liq.        | 183—184      | 16 |
|                                | s.             | s.       | s.                   | 64.5        | 220          | 17 |
|                                |                |          |                      | liq.        | 39—40        | 18 |
| 0.6783/0°                      |                |          |                      | liq.        | 36.8/750mm.  | 19 |
|                                |                |          |                      |             | 21—24        | 20 |
| 0.987/0°                       | m.             | m.       | m.                   | liq.        | 177          | 21 |
|                                | s.s.           |          |                      | 42          | expl.        | 22 |
|                                | i.             | c.v.s.s. |                      | 206         |              | 23 |
| 0.989/29°                      | i.             | m.       | m.                   | 22.5        | 232          | 24 |
|                                | h.v.s.         | s.       | s.                   |             | 185          | 25 |
|                                | i.             | v.s.s.   | s.s.                 | 120         |              | 26 |
| 1.023/15°                      | 3 : 100        | v.s.     | v.s.                 | - 6.2       | 184.4        | 27 |
| 1.2215/4°                      | v.s.           | v.s.     |                      | 192         | 245          | 28 |
| 1.11/26°                       |                |          |                      | 45          | 258.8        | 29 |
| 1.1228/18°                     | s.s.           | m.       | m.                   | 0           | 248          | 30 |
| 1.38/4°                        | v.s.s.         | s.       | s.                   | 184.2       | 275—280      | 31 |
| 1.108/26°                      |                | s.       | s. a.c.              | 2.5         | 218          | 32 |
|                                |                |          |                      |             | 243/755mm.   | 33 |
| 1.0711/55°                     |                | s.       | s. a.c.              | 57.2        | 239.5/755mm. | 34 |
|                                |                | c.v.s.   |                      | 120         |              | 35 |
| 1.0124/0°                      | i.             | s.       | s.                   | - 37.8      | 153.8        | 36 |

| Name.                    | Formula.   | Formula Weight. | Empirical Formula. |
|--------------------------|--|-----------------|--------------------|
| 1 Anthracenē             | $C_6H_4 : C_2H_2 : C_6H_4$   | 178.26          | $C_{14}H_{10}$     |
| 2 — carboxylic acid, 9   | $C_6H_4 : C_2H(COOH) : C_6H_4$   | 222.16          | $C_{15}H_{10}O_2$  |
| 3 — — —, 1               | $C_6H_4 : C_2H_2 : C_6H_3.COOH$  | 222.16          | „                  |
| 4 — — —, 2               | „ „ „  | 222.16          | „                  |
| 5 — dihydro              | $C_6H_4 : C_2H_4 : C_6H_4$   | 180.17          | $C_{14}H_{12}$     |
| 6 — hexahydro            | $C_6H_{16}$  | 184.20          | $C_{14}H_{16}$     |
| 7 Anthrachrysone         | $C_{14}H_4(OH)_2O_2$ 1:3:5:7   | 272.13          | $C_{14}H_8O_6$     |
| 8 Anthraflavic acid, see | Dihydroxy anthraquinone  |                 |                    |
| 9 Anthragallol, see      | Trihydroxy anthraquinone   |                 |                    |
| 10 Anthraminē            | $C_6H_4 : C_2H_2 : C_6H_3.NH_2$  | 193.17          | $C_{14}H_{11}N$    |
| 11 Anthranil             | $C_6H_4 \begin{array}{c} \diagup CO \\   \\ \diagdown NH \end{array}$                            | 119.09          | $C_7H_5ON$         |
| 12 Anthranilic acid, see | Amino benzoic acid, <i>o</i>   |                 |                    |
| 13 Anthranol             | $C_6H_4 \begin{array}{c} \diagup CH \\   \\ \diagdown C(OH) \end{array} C_6H_4$                  | 194.15          | $C_{14}H_{10}O$    |
| 14 Anthrapurpurin, see   | Trihydroxy anthraquinone   |                 |                    |
| 15 Anthraquinoline       | $C_6H_4 : C_2H_2 : C_6H_2 \begin{array}{c} \diagup CH : OH \\   \\ \diagdown N : OH \end{array}$ | 229.18          | $C_{17}H_{11}N$    |
| 16 Anthraquinone         | $C_6H_4 : (CO)_2 : C_6H_4$   | 208.13          | $C_{14}H_8O_2$     |
| 17 Anthrarufin, see      | Dihydroxy anthraquinone  |                 |                    |
| 18 Anthrol               | $C_6H_4 : C_2H_2 : C_6H_3.OH$  | 194.15          | $C_{14}H_{10}O$    |
| 19 Antimony penta-       | $Sb(OH_3)_5$   | 193.35          | $C_5H_{15}Sb$      |
| methy                    |  |                 |                    |
| 20 — tri-ethyl           | $Sb(C_2H_5)_3$   | 207.35          | $C_6H_{15}Sb$      |
| 21 — trimethyl           | $Sb(CH_3)_3$   | 165.29          | $C_3H_9Sb$         |
| 22 Antipyrine, 1-phenyl  | $C_6H_5.N.CO.OH$   | 188.17          | $C_{11}H_{12}ON_2$ |
| 2 : 3-dimethyl-          | $\begin{array}{c}   \\ OH_3.N — C \begin{array}{c}    \\ CH_3 \end{array} \end{array}$           |                 |                    |
| pyrazolone               |  |                 |                    |
| 23 Aposafuranone, see    | Benzene indone   |                 |                    |
| 24 Arabin                | $C_{10}H_{18}O_9$  | 282.19          | $C_{10}H_{18}O_9$  |
| 25 Arabinose, 1.         | $C_4H_5(OH)_4CHO$  | 150.11          | $C_5H_{10}O_5$     |
| 26 Arabite, 1.           | $C_5H_7(OH)_5$   | 152.12          | $C_5H_{12}O_5$     |
| 27 Arabonic acid, 1.     | $CH_2OH(CHOH)_3COOH$   | 166.11          | $C_5H_{10}O_6$     |
| 28 Arachidic acid        | $C_{20}H_{40}O_2$  | 312.42          | $C_{20}H_{40}O_2$  |
| 29 Arbutin               | $2C_6H_{16}O_7.H_2O$   | 562.40          | $C_{12}H_{16}O_7$  |
| 30 Arsenic di-ethyl      | $As(C_2H_5)_2$   | 133.06          | $C_4H_{10}As$      |
| 31 — dimethyl            | $As(CH_3)_2$   | 105.02          | $C_2H_6As$         |

| Density<br>H <sub>2</sub> O=1. | Solubility in |               |            | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|---------------|---------------|------------|-------------|-------------|----|
|                                | Water.        | Alcohol.      | Ether.     |             |             |    |
| 1.147                          | i.            | 0.076:100/16° | s.s.       | 216.6       | 351         | 1  |
|                                | h.s.s.        | s.            |            | 206 d.      |             | 2  |
|                                | i.            | s.            | s.s.       | 260         | subl.       | 3  |
|                                |               | s.s.          | s. acetic  | >280        | subl.       | 4  |
|                                | i.            | s.            | s.         | 104—105     | 313         | 5  |
|                                | i.            | s.            | s.         | 63          | 290         | 6  |
|                                | i.            | s.            | s.s.       | >360        |             | 7  |
|                                |               |               |            |             |             | 8  |
|                                |               |               |            |             |             | 9  |
|                                | v.s.s.        | s.s.          | s.s.       | 238         |             | 10 |
|                                | h.s.          | s.            | s.         |             | 210—215 d.  | 11 |
|                                |               |               |            |             |             | 12 |
|                                |               | s.            | s.h. alk.  | 163—170 d.  |             | 13 |
|                                |               |               |            |             |             | 14 |
|                                | i.            | s.            | s.         | 170         | 446         | 15 |
| 1.425                          | i.            | 0.05:100/18°  | s.s.       | 277         | 379—381     | 16 |
|                                |               |               |            |             |             | 17 |
|                                | v.s.s.        | v.s.          | s. acetone | d. 250      |             | 18 |
|                                | i.            |               |            | 96—100      |             | 19 |
| 1.324                          | i.            | s.            | s.         | liq.        | 158.5       | 20 |
| 1.523/15°                      | s.s.          | i.            | s.         | liq.        | 80.6        | 21 |
|                                | s.            | s.            | s.s.       | 114         | 309/174mm   | 22 |
|                                |               |               |            |             |             | 23 |
|                                | v.s.          | v.s.s.        |            |             |             | 24 |
|                                | s.            | i.            | i.         | 160         |             | 25 |
|                                | h.s.          |               |            | 102         |             | 26 |
|                                | s.            |               |            | 89          |             | 27 |
|                                |               |               |            | 77.5        | 238         | 28 |
|                                | h.v.s.        | s.s.          | i.         | 195         |             | 29 |
| >H <sub>2</sub> O              | i.            | s.            | s.         | liq.        | 185—190     | 30 |
| 1.15/15°                       |               |               |            | liq.        | 149         | 31 |

| Name.                          | Formula.  | Formula Empirical Weight. | Formula  |
|--------------------------------|---|---------------------------|--|
| 1 Arsenic trimethyl            | $\text{As}(\text{CH}_3)_3$  | 120.05                    | $\text{C}_3\text{H}_9\text{As}$                  |
| 2 Asparagine, see              | Amino succinamic acid   |                           |  |
| 3 Atrolactic acid              | $2\text{CH}_3 \cdot \text{C}(\text{C}_6\text{H}_5)(\text{OH})\text{COOH}$<br>$\cdot \text{H}_2\text{O}$ | 350.27                    | $\text{C}_9\text{H}_{10}\text{O}_3$              |
| 4 Atropic acid                 | $\text{CH}_2 : \text{C}(\text{C}_6\text{H}_5)\text{COOH}$   | 148.11                    | $\text{C}_9\text{H}_8\text{O}_2$                 |
| 5 Auramine                     | $\text{C}_{17}\text{H}_{21}\text{N}_3$  | 267.28                    | $\text{C}_{17}\text{H}_{21}\text{N}_3$           |
| 6 Aurine, Corraline            | $(\text{C}_6\text{H}_4\text{OH})_2 : \text{C} \text{ C}_6\text{H}_4 : \text{O}$                         | 290.21                    | $\text{C}_{19}\text{H}_{14}\text{O}_3$           |
| 7 Azelaic acid                 | $\text{C}_9\text{H}_{16}\text{O}_4$   | 188.17                    | $\text{C}_9\text{H}_{16}\text{O}_4$              |
| 8 Aziminobenzene               |                        | 119.10                    | $\text{C}_6\text{H}_5\text{N}_3$                 |
| 9 Azobenzene                   | $\text{C}_6\text{H}_5 \cdot \text{N} : \text{N} \cdot \text{O} \text{ C}_6\text{H}_5$                   | 182.16                    | $\text{C}_{12}\text{H}_{10}\text{N}_2$           |
| 10 Azobenzoic acid, <i>o</i>   | $\text{C}_{14}\text{H}_{10}\text{N}_2\text{O}_4$  | 270.17                    | $\text{C}_{14}\text{H}_{10}\text{O}_4\text{N}_2$ |
| 11 —, <i>m</i>                 | $2\text{C}_{14}\text{H}_{10}\text{N}_2\text{O}_4 \cdot \text{H}_2\text{O}$                              | 558.36                    | "  |
| 12 —, <i>p</i>                 | "   | 558.36                    | "  |
| 13 Azodicarbonamide            | $\text{NH}_2 \cdot \text{CO} \cdot \text{N}_2 \cdot \text{CONH}_2$                                      | 116.08                    | $\text{C}_2\text{H}_4\text{O}_2\text{N}_4$       |
| 14 Azonaphthalene, 2 : 2'      | $(\text{C}_{10}\text{H}_7)_2\text{N}_2$   | 282.23                    | $\text{C}_{20}\text{H}_{14}\text{N}_2$           |
| 15 —, 1 : 1'                   | " "   | 282.23                    | "  |
| 16 —, 1 : 2'                   | " "   | 282.23                    | "  |
| 17 Azophenol, <i>o</i>         | $(\text{C}_6\text{H}_4\text{OH})_2\text{N}_2$   | 214.16                    | $\text{C}_{12}\text{H}_{10}\text{O}_2\text{N}_2$ |
| 18 —, <i>p</i>                 | " "   | 214.16                    | "  |
| 19 Azophenetole, <i>o</i>      | $(\text{C}_6\text{H}_4 \cdot \text{OCH}_3)_2\text{N}_2$   | 246.23                    | $\text{C}_{14}\text{H}_{18}\text{O}_2\text{N}_2$ |
| 20 —, <i>p</i>                 | " "   | 246.23                    | "  |
| 21 Azophenylene, see           | Phenazine   |                           |  |
| 22 Azotoluene, 2 : 2'          | $(\text{C}_7\text{H}_7)_2\text{N}_2$  | 210.20                    | $\text{C}_{14}\text{H}_{14}\text{N}_2$           |
| 23 —, 3 : 3'                   | " "   | 210.20                    | "  |
| 24 —, 4 : 4'                   | " "   | 210.20                    | "  |
| 25 Azoxyanisole, <i>p</i>      | $(\text{CH}_3\text{O} \cdot \text{C}_6\text{H}_4 \cdot \text{N})_2\text{O}$                             | 258.20                    | $\text{C}_{14}\text{H}_{14}\text{O}_3\text{N}_2$ |
| 26 Azoxybenzene                | $(\text{C}_6\text{H}_5)_2\text{N}_2\text{O}$  | 198.16                    | $\text{C}_{12}\text{H}_{10}\text{ON}_2$          |
| 27 Azoxybenzoic acid, <i>o</i> | $\text{C}_{14}\text{H}_{10}\text{N}_2\text{O}_5$  | 286.17                    | $\text{C}_{14}\text{H}_{10}\text{O}_5\text{N}_2$ |
| 28 —, <i>m</i>                 | " "   | 286.17                    | "  |
| 29 —, <i>p</i>                 | " "   | 286.17                    | "  |
| 30 Azoxynaphthalene, 1 : 1'    | $(\text{C}_{10}\text{H}_7)_2\text{N}_2\text{O}$   | 298.23                    | $\text{C}_{20}\text{H}_{14}\text{ON}_2$          |
| 31 —, 2 : 2'                   | " "   | 298.23                    | "  |
| 32 Azoxyphenetole, <i>p</i>    | $(\text{C}_2\text{H}_5\text{O} \cdot \text{C}_6\text{H}_4 \cdot \text{N})_2\text{O}$                    | 286.24                    | $\text{C}_{16}\text{H}_{18}\text{O}_3\text{N}_2$ |
| 33 Barbituric acid, see        | Malonyl urea  |                           |  |
| 34 Bassorin                    | $\text{C}_6\text{H}_{10}\text{O}_5$   | 162.11                    | $\text{C}_6\text{H}_{10}\text{O}_5$              |
| 35 Behenic acid                | $\text{CH}_3(\text{CH}_2)_{20}\text{COOH}$  | 340.46                    | $\text{C}_{22}\text{H}_{44}\text{O}_2$           |
| 36 Behenolic acid              | $\text{C}_{22}\text{H}_{40}\text{O}_2$  | 336.43                    | $\text{C}_{22}\text{H}_{40}\text{O}_2$           |

| Density<br>$H_2O=1.$ | Solubility in |           |                                      | M.P.<br>°C. | B.P.<br>°C. |    |
|----------------------|---------------|-----------|--------------------------------------|-------------|-------------|----|
|                      | Water.        | Alcohol.  | Ether.                               |             |             |    |
|                      |               |           |                                      | liq.        | <100        | 1  |
|                      |               |           |                                      |             |             | 2  |
|                      | h.m.          |           |                                      | 93—94       |             | 3  |
|                      | 1:692/19°     |           | s. CS <sub>2</sub>                   | 106.5       | 267 d       | 4  |
|                      | i.            | s.s.      | i.                                   | 136         |             | 5  |
|                      | i.            | s.        | s. alk.                              | d. 220      |             | 6  |
|                      | h.v.s.        | v.s.      | v.s.                                 | 106         | 360         | 7  |
| 1.18—1.23            |               | s.        | s. C <sub>6</sub> H <sub>6</sub>     | 98.5        |             | 8  |
| 1.203                | i.            | s.        | s.                                   | 68          | 297         | 9  |
|                      | v.s.s.        | s.        |                                      | d. 237      |             | 10 |
|                      | s.s.          | s.s.      | s.s.                                 |             | d           | 11 |
|                      | i.            | i.        | i.                                   |             | d.          | 12 |
|                      | v.s.s.        | i.        |                                      | d. 180      |             | 13 |
|                      | i.            | s.s.      | s. acetic                            | 204         |             | 14 |
|                      | i.            |           | s. acetic                            | 190         |             | 15 |
|                      | i.            |           | s. acetic                            | 136         |             | 16 |
|                      | i.            | 1:300     | v.s. KOH                             | 171         | subl.       | 17 |
|                      | s.s.          | s.        | s., s. C <sub>6</sub> H <sub>6</sub> | 216—218     |             | 18 |
|                      | i.            | s.        | s., s. HCl                           | 131         | d. 240      | 19 |
|                      | i.            | h.s.      | v.s.                                 | 167         |             | 20 |
|                      |               |           |                                      |             |             | 21 |
|                      | i.            | s.        | s., s. C <sub>6</sub> H <sub>6</sub> | 55          |             | 22 |
|                      | i.            | s.        | s.                                   | 54—55       |             | 23 |
|                      | i.            | s.s.      | s.                                   | 144         |             | 24 |
|                      |               | s.        |                                      | 117.3       |             | 25 |
| 1.246/20°            | i.            | s         | s.                                   | 36          |             | 26 |
|                      | s.s.          | h.s.      | s.s.                                 | 254—255     |             | 27 |
|                      | i.            | s.s.      | s.s.                                 | 345         |             | 28 |
|                      | i.            | i.        | s. C <sub>5</sub> H <sub>5</sub> N   | d. 240      |             | 29 |
|                      | i.            | i.        | i., s. CHCl <sub>3</sub>             | 127         |             | 30 |
|                      | i.            | i.        | i.                                   | 167—168     |             | 31 |
|                      |               | s.        |                                      | 137 (corr.) |             | 32 |
|                      |               |           |                                      |             |             | 33 |
|                      | s.s.          | i.        |                                      |             |             | 34 |
|                      | i.            | s. (abs.) |                                      | 83          |             | 35 |
|                      | i.            | v.s.      |                                      | 57.5        |             | 36 |

| Name.                                       | Formula.   | Formula Empirical<br>Weight. Formula. |
|---|--|---------------------------------------|
| 1 Benzal acetone                            | $C_6H_5.C_2H_2.CO.CH_3$  | 146.13 $C_{10}H_{10}O$                |
| 2 — acetophenone                            | $C_6H_5.C_2H_2.CO.C_6H_5$  | 208.17 $C_{15}H_{12}O$                |
| 3 — acetoacetic ester                       | $CH_3.CO.O:CH.C_6H_5$  | 218.18 $C_{13}H_{14}O_3$              |
|   | $COOC.H_5$   |                                       |
| 4 — azine                                   | $C_6H_5.CH:N.N:CH.C_6H_5$  | 208.19 $C_{14}H_{12}N_2$              |
| 5 — chloride                                | $C_6H_5.CHCl$  | 161.00 $C_7H_8Cl$                     |
| 6 — cyanhydrin                              | $C_6H_5.CH(OH)CN$  | 133.11 $C_8H_7ON$                     |
| 7 — hydrazine                               | $C_6H_5.CH:N.NH_2$   | 120.12 $C_7H_8N_2$                    |
| 8 — malonic acid                            | $C_6H_5.CH:O:(COOH)_2$   | 192.11 $C_{10}H_8O_4$                 |
| 9 — phenylhydrazine                         | $C_6H_5.CH:N.NH.C_6H_5$  | 196.18 $C_{13}H_{12}N_2$              |
| 10 Benzaldehyde                             | $C_6H_5.CHO$   | 106.08 $C_7H_6O$                      |
| 11 — sulphonie acid, <i>o</i>               | $CHO.C_6H_4.SO_3H$   | 186.14 $C_7H_6O_4S$                   |
| 12 Benzaldoxime, <i>anti</i>                | $C_6H_5.CH:N.OH$   | 121.10 $C_7H_7ON$                     |
| 13 —, <i>syn</i> .                          | " "  | 121.10 "                              |
| 14 — carboxylic acid<br>anhydride, <i>o</i> | $C_6H_4 \begin{matrix} \swarrow CO.O \\ \downarrow CH:N \end{matrix}$                          | 147.09 $C_8H_5O_2N$                   |
|   | $C_6H_5.CH(C_6H_5).CO.C_6H_5$  |                                       |
| 15 Benzamarone                              | $C \begin{matrix} \swarrow CH(C_6H_5)CO.C_6H_5 \\ \downarrow CH(C_6H_5)CO.C_6H_5 \end{matrix}$ | 480.40 $C_{35}H_{28}O_2$              |
| 16 Benzamide                                | $C_6H_5.CO.NH_2$   | 121.16 $C_7H_7ON$                     |
| 17 Benzamidine                              | $C_6H_5.C(NH)NH_2$   | 120.12 $C_7H_8N_2$                    |
| 18 Benzanilide                              | $C_6H_5.CONH.C_6H_5$   | 197.16 $C_{13}H_{11}ON$               |
| 19 Benzaurine                               | $C_6H_5.C:C_6H_4:O$  | 274.21 $C_{19}H_{16}O_3$              |
|   | $C_6H_4OH$   |                                       |
| 20 Benzene                                  | $C_6H_6$   | 78.08 $C_6H_6$                        |
| 21 — disulphochloride, <i>m</i>             | $C_6H_4(SO_2Cl)_2$   | 275.10 $C_6H_4O_4Cl_2S_2$             |
| 22 — hexachloride                           | $C_6H_4Cl_6$   | 290.84 $C_6H_4Cl_6$                   |
| 23 — indone                                 | $C_{18}H_{12}N_2O$   | 272.21 $C_{18}H_{12}ON_2$             |
| 24 — pentacarboxylic<br>acid                | $C_6H(COOH)_5.5H_2O$   | 388.18 $C_{11}H_6O_{10}$              |
| 25 — sulphamide                             | $C_6H_5.SO_2.NH_2$   | 157.16 $C_6H_5O_2NS$                  |
| 26 — sulphinic acid                         | $C_6H_5.SO_2H$   | 142.14 $C_6H_5O_2S$                   |
| 27 — sulphochloride                         | $C_6H_5.SO_2Cl$  | 176.59 $C_6H_5O_2SOl$                 |
| 28 — sulphonie acid                         | $C_6H_5.SO_2.H.H_2O$   | 176.16 $C_6H_5O_2S$                   |
| 29 — trisulphonie acid                      | $C_6H_3(SO_3H)_3$  | 318.26 $C_6H_3O_9S_3$                 |
| 30 Benzenyl amidoxime                       | $C_6H_5.C(:NOH)NH_2$   | 136.20 $C_7H_8ON_2$                   |

| Density<br>H <sub>2</sub> O=1. | Solubility in |                      |                                    | M.P.<br>°C.                                | B.P.<br>°C. |    |
|--------------------------------|---------------|----------------------|------------------------------------|--|-------------|----|
|                                | Water.        | Alcohol.             | Ether.                             |  |             |    |
| 1.008                          | i.            | s.                   | s.                                 | 41—42                                      | 260—262     | 1  |
|                                | i.            | s.                   | s.                                 | 62   | 345—348     | 2  |
|                                |               | s.                   |                                    | 59—60                                      | 181/17mm    | 3  |
|                                | i.            | h.v.s.               | v.s.                               | 93   | d.          | 4  |
| 1.295/16°                      |               |                      |                                    | -16.1                                      | 203.5       | 5  |
| 1.124                          | i.            | s.                   | s.                                 | S.P. -10                                   | d 170       | 6  |
|                                |               | s.                   | s.                                 | 16   | 140/14mm.   | 7  |
|                                | s.s.          | h.s.                 | s.s.                               | d. 195—196                                 |             | 8  |
|                                |               | h.s.                 | s.s.                               | 156  | 235—239/55  | 9  |
| 1.0455/20°                     | 1: 300        | s.                   |                                    | -26  | 179.5       | 10 |
|                                | s.            |                      |                                    | 114  |             | 11 |
| 1.11/20°                       | s.s.          | v.s.                 | v.s.                               | 20.5                                       | 152—153/53  | 12 |
|                                |               |                      | v.s.                               | 128—130                                    |             | 13 |
|                                |               |                      |                                    | 145 becomes                                |             | 14 |
|                                |               |                      |                                    | C <sub>6</sub> H <sub>4</sub> (ON)<br>COOH |             |    |
|                                | 1: 157 h.     | s.s.                 | s.s. C <sub>6</sub> H <sub>6</sub> | 219,<br>iso 180                            |             | 15 |
| 1.341/4°                       | s.s.          | s.                   | s.                                 | 130  | 290         | 16 |
|                                | s.            | v.s.                 | s.s.                               | 75—80                                      |             | 17 |
| 1.31/4°                        | i.            | s.                   | s.s.                               | 164  |             | 18 |
|                                | i.            | s.                   | s.                                 | 100  |             | 19 |
| 0.87907/20°                    | 0.2: 100      | s.                   | s.                                 | 5.4  | 80.2        | 20 |
|                                |               |                      |                                    | 63   | 210.7/20mm. | 21 |
| 1.87/20°                       |               | s. OHCl <sub>3</sub> | s. C <sub>6</sub> H <sub>6</sub>   | 157  | 288         | 22 |
|                                | s.s.          | s.                   | s. C <sub>6</sub> H <sub>6</sub>   | 284—249                                    |             | 23 |
|                                | v.s.          |                      |                                    | d.   |             | 24 |
|                                | s.s.          | h.v.s.               | s.                                 | 141 d.                                     |             | 25 |
|                                | h.s.          | s.                   | s.                                 | 83—84                                      | d. 100      | 26 |
| 1.3830/15°                     | i.            | s.                   | s.                                 | 14.5                                       | d. 247      | 27 |
|                                | v.s.          | v.s.                 | i.                                 | 65—66                                      | 135—137     | 28 |
|                                | del.          |                      |                                    |  |             | 29 |
|                                | h.s.          | s.                   | s.                                 | 88   |             | 30 |

| Name.                           | Formula.  | Formula Weight. | Empirical Formula.      |
|---------------------------------|---|-----------------|-------------------------|
| 1 Benzenyl amido thiophenol     | $C_6H_4 \begin{array}{c} \diagup N \\ \diagdown S \end{array} C_6H_5$               | 211.21          | $C_{13}H_9NS$           |
| 2 — naphthylamidine             | $C_6H_5.O(NH)NH.C_{10}H_7$  | 246.22          | $C_{17}H_{14}N_2$       |
| 3 — phenyleneamidine            | $C_6H_5.O \begin{array}{c} \diagup NH \\ \diagdown N \end{array} C_6H_4$            | 194.17          | $C_{13}H_{10}N_2$       |
| 4 Benzhydrol                    | $(C_6H_5)_2:CHOH$   | 184.16          | $C_{13}H_{12}O$         |
| 5 — ether                       | $[(C_6H_5)_2:CH]_2O$  | 350.31          | $C_{26}H_{22}O$         |
| 6 Benzhydroxamic acid           | $C_6H_5.C(:NOH)OH$  | 137.11          | $C_7H_7O_2N$            |
| 7 Benzhydryl amine              | $(C_6H_5)_2:CH.NH_2$  | 183.18          | $C_{13}H_{13}N$         |
| 8 — benzoic acid, <i>p</i>      | $C_6H_5.CH(OH)C_6H_4.COOH$  | 228.17          | $C_{14}H_{12}O_2$       |
| 9 Benzidine, <i>p</i>           | $NH_2.C_6H_4.C_6H_4.NH_2$   | 184.18          | $C_{12}H_{12}N_2$       |
| 10 — disulphonic acid, <i>p</i> | $(NH_2)_2C_6H_4(SO_3H)_2$   | 344.30          | $C_{12}H_{12}O_6N_2S_2$ |
| 11 — sulphone                   | $C_6H_5(C_6H_5)_2SO_2$  | 246.22          | $C_{12}H_{10}O_2S_2$    |
| 12 Benzil                       | $C_6H_5.CO.CO.C_6H_5$   | 210.15          | $C_{13}H_{10}O_2$       |
| 13 — dioxime, $\alpha$          | $C_6H_5.C(NO_2H).C(NO_2H)C_6H_5$  | 240.19          | $C_{14}H_{12}O_2N_2$    |
| 14 —, $\beta$                   | " "   | 240.19          | "                       |
| 15 —, $\gamma$                  | " "   | 240.19          | "                       |
| 16 — monoxim <i>o</i>           | $C_6H_5.CO.C(NO_2H)C_6H_5$  | 225.17          | $C_{14}H_{11}O_2N$      |
| 17 —, $\gamma$                  | " "   | 225.17          | "                       |
| 18 — imide                      | $C_6H_5.C(OH) \begin{array}{c} \diagup O-C_6H_5 \\ \diagdown NH.C_6H_5 \end{array}$ | 315.25          | $C_{21}H_{17}O_2N$      |
| 19 — osazone                    | $C_6H_5.C:N.NH.C_6H_5$<br>$C_6H_5.C:N.NH.C_6H_5$                                    | 390.35          | $C_{26}H_{22}N_4$       |
| 20 Benzilic acid                | $(C_6H_5)_2C(OH)COOH$   | 228.17          | $C_{14}H_{12}O_3$       |
| 21 Benzimidazole, <i>o</i>      | $C_6H_4 \begin{array}{c} \diagup N \\ \diagdown NH \end{array} CH$                  | 118.10          | $C_7H_6H_2$             |
| 22 Benzimidazolone, <i>o</i>    | $C_6H_4:(NH)_2:CO$  | 134.10          | $C_7H_6ON_2$            |
| 23 Benzoic acid                 | $C_6H_5.COOH$   | 122.08          | $C_7H_6O_2$             |
| 24 Benzoate, calcium            | $(C_6H_5COO)_2Ca.(3H_2O)$   | 282.22          | $C_{14}H_{10}O_4Ca$     |
| 25 —, ferric, basic             | $(C_6H_5COO)_3Fe.(OH)_3$  | 525.93          | $C_{21}H_{18}O_9Fe_2$   |
| 26 —, sodium                    | $C_6H_5.COONa.(H_2O)$   | 144.08          | $C_7H_5O_2Na$           |
| 27 —, allyl                     | $C_6H_5.COOC_3H_5$  | 162.13          | $C_{10}H_{10}O_2$       |
| 28 —, amyl <i>iso</i>           | $C_6H_5.COOC_5H_{11}$   | 192.19          | $C_{12}H_{14}O_2$       |
| 29 —, benzyl                    | $C_6H_5.COOCH_2.C_6H_5$   | 212.17          | $C_{14}H_{12}O_2$       |
| 30 —, ethyl                     | $C_6H_5.COOC_2H_5$  | 150.13          | $C_9H_{10}O_2$          |



| Density<br>$H_2O=1$ | Solubility in |          |              | M.P.<br>°C. | B.P.<br>°C.    |    |
|---------------------|---------------|----------|--------------|-------------|----------------|----|
|                     | Water.        | Alcohol. | Ether.       |             |                |    |
|                     | i.            | s.       | s.           | 115         | 360            | 1  |
|                     | i.            | s.       |              | 141         |                | 2  |
|                     | s.s.          | s.       | s. acetic    | 280         |                | 3  |
|                     | 1:2000/20°    | v.s.     | v.s.         | 69          | 297—298/748    | 4  |
|                     |               | s.s.     | s. $C_6H_6$  | 109         | 267/15mm.      | 5  |
|                     | 1:44.5/6°     | v.s.     | s.s.         | 124—125     |                | 6  |
|                     |               |          |              | 34—35       | 303.6          | 7  |
|                     | h.s.          | s.       | s.           | 164—165     | d.             | 8  |
| 1.251               | c.s.s.        | s.       | s.           | 128         | 400/740mm.     | 9  |
|                     | s.s.          | v.s.s.   | v.s.s.       |             |                | 10 |
|                     | i.            | i.       | i.           | >350        |                | 11 |
|                     | i.            | s.       | s.           | 95          | 347            | 12 |
|                     | i.            | s.s.     | s.s.         | 237 d.      |                | 13 |
|                     | h.s.s.        | s.       | s.           | 206—207 d.  |                | 14 |
|                     | i.            | v.s.     | s.           | 165         |                | 15 |
|                     | s.s.          | v.s.     | v.s.         | 137—138     |                | 16 |
|                     | i.            | v.s.     | s.           | 114         |                | 17 |
|                     |               | s.       |              | 137—138     |                | 18 |
|                     | i.            | s.s.     | s.s.         | 225         |                | 19 |
|                     | c.s.s.        | s.       | s.           | 150         |                | 20 |
|                     | s.            | s.       | s. ac., alk. | 170         |                | 21 |
|                     | h.s.s.        | s.       |              | 312         |                | 22 |
| 1.337               | 0.29:100/20°  | s.       | s.           | 121—122     | 249.2          | 23 |
| 1.435—1.475         | 1:27.7/5°     |          |              |             |                | 24 |
|                     | i.            |          |              |             |                | 25 |
|                     | v.s.          | 1:13     |              |             |                | 26 |
|                     |               |          |              |             | 230/768mm.     | 27 |
| 1.004/0°            |               |          |              |             | 262            | 28 |
| 1.114/18°           |               | s.       |              | <20         | 315—320        | 29 |
| 1.0502/16°          | h.s.s.        | s.       | s.           | -34.2       | 212.9/745.5mm. | 30 |

| Name.                          | Formula.  | Formula Weight. | Empirical Formula. |
|--------------------------------|---|-----------------|--------------------|
| 1 Benzoate, ethylene           | $(C_6H_5.COO)_2C_2H_4$  | 270.19          | $C_{16}H_{14}O_4$  |
| 2 —, methyl                    | $C_6H_5.COOC_6H_5$  | 136.10          | $C_8H_8O_2$        |
| 3 — naphthyl, $\alpha$         | $C_6H_5.COO.C_{10}H_7$  | 248.18          | $C_{17}H_{12}O_2$  |
| 4 —, $\beta$                   | " "   | 248.18          | " "                |
| 5 — phenyl                     | $C_6H_5.COOC_6H_5$  | 198.14          | $C_{13}H_{10}O_2$  |
| 6 — tolyl, $o$                 | $C_6H_5.COOC_6H_4.CH_3$   | 212.17          | $C_{14}H_{12}O_2$  |
| 7 —, $m$                       | " "   | 212.17          | " "                |
| 8 —, $p$                       | " "   | 212.17          | " "                |
| 9 Benzoic anhydride            | $(C_6H_5.CO)_2O$  | 226.15          | $C_{14}H_{10}O_3$  |
| 10 Benzoïn, d., l.             | $C_6H_5.CH(OH)CO.C_6H_5$  | 212.17          | $C_{14}H_{12}O_2$  |
| 11 —, r.                       | " "   | 212.17          | " "                |
| 12 Benzo nitrile               | $C_6H_5.CN$   | 103.09          | $C_7H_5N$          |
| 13 — phenone                   | $(C_6H_5)_2:CO$   | 182.15          | $C_{13}H_{10}O$    |
| 14 — dicarboxylic acid, 2 : 2' | $(C_6H_4.COOH)_2:CO$  | 270.16          | $C_{15}H_{10}O_5$  |
| 15 — oxime                     | $(C_6H_5)_2:C:NOH$  | 197.16          | $C_{13}H_{11}ON$   |
| 16 — trichloride               | $C_6H_5.CCl_3$  | 195.46          | $C_7H_5Cl_3$       |
| 17 Benzophosphinic acid        | $COOH.C_6H_4.PO(OH)_2(p)$   | 202.13          | $C_7H_7O_5P$       |
| 18 Benzoxazole                 | $C_6H_4 \begin{array}{c} \diagup O \diagdown \\ \diagdown N \diagup \end{array} CH$ | 119.09          | $C_7H_5ON$         |
| 19 Benzoyl acetic acid         | $C_6H_5.CO.CH_2COOH$  | 164.11          | $C_9H_8O_3$        |
| 20 — acetone                   | $C_6H_5.CO.CH_2COCH_3$  | 162.13          | $C_{10}H_{10}O_2$  |
| 21 — acetonitrile              | $C_6H_5.CO.CH_2CN$  | 145.11          | $C_8H_7ON$         |
| 22 — 1-anthraquinone           | $C_6H_4:(CO)_2:C_6H_3.CO.C_6H_5$  | 312.20          | $C_{21}H_{12}O_3$  |
| 23 — amino benzoic acid, $o$   | $C_7H_5O.NH.C_6H_4.COOH$  | 241.17          | $C_{14}H_{11}O_3N$ |
| 24 — — — —, $m$                | " "   | 241.17          | " "                |
| 25 — — — —, $p$                | " "   | 241.17          | " "                |
| 26 — azide                     | $C_6H_5.CO.N \begin{array}{c} \diagup N \diagdown \\   \\ N \end{array}$            | 147.11          | $C_7H_5ON_3$       |
| 27 — benzoic acid, $o$         | $C_6H_5.CO.C_6H_4COOH.H_2O$   | 244.22          | $C_{14}H_{10}O_3$  |
| 28 — — —, $m$                  | $C_6H_5.CO.C_6H_4COOH$  | 226.15          | " "                |
| 29 — — —, $p$                  | " "   | 226.15          | " "                |
| 30 — bromide                   | $C_6H_5.CO.Br$  | 185.00          | $C_7H_5OBr$        |
| 31 — chloride                  | $C_6H_5.CO.Cl$  | 140.54          | $C_7H_5OCl$        |
| 32 — cyanide                   | $C_6H_5.CO.CN$  | 131.09          | $C_8H_5ON$         |
| 33 — cyclo-butane              | $C_6H_5.CO.CH:(CH_2)_2:CH_2$  | 160.15          | $C_{11}H_{12}O$    |

| Density<br>H <sub>2</sub> O=1. | Solubility in |          |         | M.P.<br>°C. | B.P.<br>°C.  |    |
|--------------------------------|---------------|----------|---------|-------------|--------------|----|
|                                | Water.        | Alcohol. | Ether.  |             |              |    |
| 1.1026/0°                      | i.            |          | s.      | 73—74       | >360         | 1  |
|                                | i.            |          |         | liq.        | 199.2/746mm. | 2  |
|                                |               |          | s.s.    | 56          |              | 3  |
|                                |               | h.s.s.   | v.s.    | 107         |              | 4  |
|                                |               | s.       | s.      | 68—69       | 314 (corr.)  | 5  |
|                                |               |          |         |             | 307          | 6  |
|                                |               |          |         | 54          | 313—314      | 7  |
|                                |               |          |         | 71.5        | 315.5—316    | 8  |
|                                |               |          |         | 42          | 360          | 9  |
|                                |               |          |         | 131—132.5   |              | 10 |
|                                |               |          |         | 129—130     |              | 11 |
| .9555/14.9°                    | i.            | s.       | s.      |             |              |    |
|                                | h.s.s.        | s.       | s.      |             |              |    |
| .0052/18°                      | 1: 100 h.     | m.       | m.      | - 17        | 191.3        | 12 |
| .1098/50°                      | i.            | s.       | s.      | 47.2        |              | 13 |
|                                | s.s.          | s.       | s.      | >300        |              | 14 |
| .38/14°                        | i.            | s.       | s. alk. | 139         |              | 15 |
|                                | d.            |          | s.      | - 21.2      | 213—214      | 16 |
|                                | s.            | s.       | i.      | >300        |              | 17 |
|                                | i.            |          |         | 30.5        | 182.5        | 18 |
|                                | s.s.          | v.s.     | v.s.    | 104 d.      |              | 19 |
| .10899/60°                     | s.s.          | v.s.     | v.s.    | 61          | 260—261      | 20 |
|                                |               | s.       | s.      | 80.5        |              | 21 |
|                                |               |          |         | 229         |              | 22 |
|                                | i.            | s.       | s.      | 182         |              | 23 |
|                                |               |          |         |             |              |    |
| .5105/4°                       | h.s.          | s.       | s.      | 174         | subl.        | 24 |
|                                | s.            | s.       | s.      | 265—266     |              | 25 |
|                                | i.            | v.s.     | v.s.    | 29—30       |              | 26 |
|                                | h.s.          |          |         | anhydr. 120 |              | 27 |
|                                | s.s.          | v.s.     | v.s.    | 161—162     |              | 28 |
| .570/15°                       | s.s.          | s.       | s.      | 194         | subl.        | 29 |
|                                |               | s.       |         | liq.        | 218—219      | 30 |
| .2122/20°                      | d.            | d.       | d.      | - 1         | 198.3/749mm. | 31 |
|                                | d.            |          |         | 32          | 205—208 d.   | 32 |
| .06/4°                         |               |          |         |             | 258—259/740  | 33 |

| Name.                                  | Formula.   | Formula Empirical | Weight. Formula.   |
|--|--|-------------------|--------------------|
| 1 Benzoyl <i>cyclo</i> -propane        | $C_6H_5CO.CH \begin{array}{c} \diagup CH_2 \\   \\ \diagdown CH_2 \end{array}$ | 146.13            | $C_{10}H_{10}O$    |
| 2 — fluoride                           | $C_6H_5CO.F$   | 124.08            | $C_7H_5OF$         |
| 3 — formic acid                        | $C_6H_5CO.COOH$  | 150.09            | $C_8H_6O_3$        |
| 4 — glycollic acid                     | $C_6H_5CO.OCH_2.COOH$  | 180.11            | $C_9H_8O_4$        |
| 5 — hydrazine                          | $C_6H_5CO.NH.NH_2$   | 136.20            | $C_7H_8ON_2$       |
| 6 — hydrogen peroxide                  | $C_6H_5CO.O.H$   | 138.08            | $C_7H_6O_3$        |
| 7 — iodide                             | $C_6H_5CO.I$   | 232.00            | $C_7H_5OI$         |
| 8 — lactic acid                        | $CH_3CH(O.C_6H_5.CO).COOH$   | 194.13            | $C_{10}H_{10}O_4$  |
| 9 — naphthylamine, $\alpha$            | $C_{10}H_7O.NH.C_6H_5$   | 247.20            | $C_{17}H_{13}ON$   |
| 10 —, $\beta$                          | " "  | 247.20            | " "                |
| 11 — peroxide                          | $(C_6H_5CO)_2O_2$  | 242.15            | $C_{14}H_{10}O_4$  |
| 12 — phenetidine, $p$                  | $C_7H_5O.NH.C_6H_4.OC_2H_5$  | 241.20            | $C_{15}H_{15}O_2N$ |
| 13 — phthalic acid, 1:2:3              | $C_6H_5CO.C_6H_3(COOH)_2$  | 270.16            | $C_{15}H_{10}O_5$  |
| 14 — —, tere, 1:2:5                    | " "  | 270.16            | " "                |
| 15 — propionic acid, $\beta$           | $C_6H_5CO.CH_2.CH_2.COOH$  | 178.13            | $C_{10}H_{10}O_3$  |
| 16 — pyrocatechol, see                 | Dihydroxy benzophenone   |                   |                    |
| 17 — salicin, see                      | Populin  |                   |                    |
| 18 — sulphide                          | $(C_6H_5CO)_2S$  | 242.21            | $C_{14}H_{10}O_2S$ |
| 19 — thiourea                          | $C_6H_5CO.NH.CS.NH_2$  | 180.18            | $C_8H_{10}ON_2S$   |
| 20 — toluidine, $o$                    | $C_6H_5CO.NH.C_6H_4CH_3$   | 211.18            | $C_{14}H_{13}ON$   |
| 21 —, $m$                              | " "  | 211.18            | " "                |
| 22 —, $p$                              | " "  | 211.18            | " "                |
| 23 — urea                              | $C_6H_5CO.NH.CO.NH_2$  | 164.12            | $C_8H_8ON_2$       |
| 24 Benzpinacone                        | $(C_6H_5)_2COH.COH:(C_6H_5)_2$   | 366.31            | $C_{26}H_{22}O_2$  |
| 25 Benzyl acetamide                    | $C_6H_5CH_2NH.COCH_3$  | 149.14            | $C_9H_{11}ON$      |
| 26 — aceto acetic abid,<br>ethyl ester | $CH_3CO.CH(C_6H_7)COOC_2H_5$   | 220.19            | $C_{13}H_{16}O_3$  |
| 27 — alcohol                           | $C_6H_5CH_2OH$   | 108.10            | $C_7H_8O$          |
| 28 — amine                             | $C_6H_5CH_2.NH_2$  | 107.18            | $C_7H_9N$          |
| 29 — aniline                           | $C_6H_5CH_2.NH.C_6H_5$   | 183.18            | $C_{13}H_{13}N$    |
| 30 — azide                             | $C_6H_5CH_2.N_3$   | 133.12            | $C_7H_7N_3$        |
| 31 — benzoic acid, $o$                 | $C_6H_5CH_2.C_6H_4.COOH$   | 212.17            | $C_{14}H_{12}O_2$  |
| 32 — —, $p$                            | " "  | 212.17            | " "                |
| 33 — bromide                           | $C_6H_5CH_2.Br$  | 171.01            | $C_7H_7Br$         |
| 34 — carbamate                         | $C_6H_5CH_2.CO_2.NH_2$   | 151.12            | $C_8H_9O_2N$       |
| 35 — chloride                          | $C_6H_5CH_2.Cl$  | 126.55            | $C_7H_7Cl$         |
| 36 — cyanide                           | $C_6H_5CH_2.CN$  | 117.11            | $C_8H_7N$          |
| 37 — cyanamide                         | $C_6H_5CH_2.NH.ON$   | 132.12            | $C_8H_8N_2$        |

| Density<br>$H_2O=1.$ | Solubility in— |             |        | M.P.<br>°C. | B.P.<br>°C.   |    |
|----------------------|----------------|-------------|--------|-------------|---------------|----|
|                      | Water.         | Alcohol     | ether. |             |               |    |
|                      |                |             |        |             | 239—239.5/720 | 1  |
| $>H_2O$              |                |             |        | liq.        | 154           | 2  |
|                      | s.             | s.          | s.     | s.          |               | 3  |
|                      | h.s.           | s.          | s.     |             |               | 4  |
|                      | v.s.           | v.s.        | s.s.   | 112.5       |               | 5  |
|                      | l.             | s.          | s.     | 41—43       | 97—110/15mm   | 6  |
|                      | d.             | s.          |        | 3           | 135/25mm.     | 7  |
|                      | h.s.           | s.          | s.     | 112         |               | 8  |
|                      |                | v.s. (abs.) |        | 165         |               | 9  |
|                      |                | h.s.s.      | s.s.   | 157—158     |               | 10 |
|                      | i.             | s. $C_6H_6$ | s.     | 104         |               | 11 |
|                      |                |             |        | 173         |               | 12 |
|                      | h.s.           | s.          |        | 155         |               | 13 |
|                      | i.             | s.          | s.     | $>290$      |               | 14 |
|                      | h.s.           | v.s.        | v.s.   | 116         |               | 15 |
|                      |                |             |        |             |               | 16 |
|                      |                |             |        |             |               | 17 |
|                      | i.             | s.s.        | s.     | 129         | d.            | 18 |
|                      | s.             | s.          | i.     | 71          |               | 19 |
|                      | h.s.s.         | s.          |        | 131         |               | 20 |
|                      |                |             |        | 125         |               | 21 |
|                      |                | v.s.        | s.     | 158         | 232           | 22 |
|                      | s. KOH         | h. 1 : 24   | i.     | 215         |               | 23 |
|                      |                | h. 1 : 39   | s.     | 185—186     |               | 24 |
|                      | i.             | v.s.        | v.s.   | 60—61       | $>300$        | 25 |
| 1.036/14.5°          |                |             |        | liq.        | 283—284       | 26 |
| 1.043/20°            | i.             | s.          | s.     | liq         | 206.5         | 27 |
| 0.9826/18.9°         | m.             | m.          | m.     | liq.        | 183           | 28 |
|                      |                | s.          |        | 35.5        | 298—300       | 29 |
|                      | i.             | m.          | m.     |             | 108/25mm      | 30 |
|                      | s.s.           | s.          | s.     | 114         | subl. 307     | 31 |
|                      | s.s.           | v.s.        | v.s.   | 154—155     | 315.5—316     | 32 |
| 1.4380/21°           | s.s.           | v.s.        | v.s.   |             | 198—199       | 33 |
|                      | s.s.           | s.          | s.     | 86          | d.            | 34 |
| 1.107/14°            | i.             | s.          | s.     | —41.3       | 179           | 35 |
| 1.0146/18°           | i.             | s.          |        | —24.6       | 231.7         | 36 |
|                      | i.             | s.          | s.     | 33          |               | 37 |

| Name.                        | Formula.                           | Formula Empirical | Weight. Formula.   |
|------------------------------|------------------------------------|-------------------|--------------------|
| 1 Benzyl cyanurate           | $(C_6H_5.CH_2.N.CO)_3$             | 399.32            | $C_{24}H_{21}O_3N$ |
| 2 — diphenyl, $\alpha$       | $C_6H_5.CH_2.C_6H_4.O_6$           | 244.22            | $C_{19}H_{16}$     |
| 3 — —, $p$                   | " "                                | 244.22            | " "                |
| 4 — diphenylamine            | $C_6H_5.CH_2.N:(C_6H_5)_2$         | 259.24            | $C_{19}H_{17}N$    |
| 5 — disulphide               | $(C_6H_5.CH_2)_2S_2$               | 246.30            | $C_{14}H_{14}S_2$  |
| 6 — ether                    | $(C_6H_5.CH_2)_2O$                 | 198.18            | $C_{14}H_{14}O$    |
| 7 — ethyl benzene            | $C_6H_5.CH_2.C_2H_5$               | 196.20            | $C_{15}H_{16}$     |
| 8 — — ether                  | $C_6H_5.CH_2.O.C_2H_5$             | 136.14            | $C_9H_{12}O$       |
| 9 — hydrazine                | $C_6H_5.CH_2.NH.NH_2$              | 122.14            | $C_7H_{10}N_2$     |
| 10 — hydroxylamine, $\alpha$ | $C_6H_5.CH_2.NH.OH$                | 123.12            | $C_7H_9ON$         |
| 11 — —, $\beta$              | " "                                | 123.12            | " "                |
| 12 — iodide                  | $C_6H_5.CH_2I$                     | 208.01            | $C_7H_7I$          |
| 13 — malonic acid            | $C_6H_5.CH_2.CH(COOH)_2$           | 194.13            | $C_{10}H_{10}O_4$  |
| 14 — mercaptan               | $C_6H_5.CH_2.SH$                   | 124.16            | $C_7H_8S$          |
| 15 — methyl ether            | $C_6H_5.CH_2.CO.CH_3$              | 134.12            | $C_9H_{10}O$       |
| 16 — naphthalene, $\alpha$   | $C_6H_5.CH_2.C_{10}H_7$            | 218.20            | $C_{17}H_{14}$     |
| 17 — —, $\beta$              | " "                                | 218.20            | " "                |
| 18 — naphthyl ketone         | $C_6H_5.CH_2.CO.C_{10}H_7$         | 268.23            | $C_{18}H_{14}O$    |
| 19 — phenanthrene            | $C_6H_5.CH_2.C_6H_3:C_2H_2:C_6H_4$ | 268.23            | $C_{21}H_{16}$     |
| 20 — phenol, $p$             | $C_6H_5.CH_2.C_6H_4OH$             | 184.16            | $C_{13}H_{12}O$    |
| 21 — phenyl carbinol         | $C_6H_5.CH_2.CHOH.C_6H_5$          | 198.18            | $C_{14}H_{14}O$    |
| 22 — pyridine, $\alpha$      | $C_6H_5.CH_2.C_5H_4N$              | 169.16            | $C_{12}H_{11}N$    |
| 23 — —, $\beta$              | " "                                | 169.16            | " "                |
| 24 — sulphide                | $(C_6H_5.CH_2)_2S$                 | 214.24            | $C_{14}H_{14}S$    |
| 25 — sulphone                | $(C_6H_5.CH_2)_2SO_2$              | 246.24            | $C_{14}H_{14}O_2S$ |
| 26 — sulphoxide              | $(C_6H_5.CH_2)_2SO$                | 230.24            | $C_{14}H_{14}OS$   |
| 27 — tartaric acid           | $C_6H_5.CH_2.C(OH)COOH$            | 240.15            | $C_{11}H_{12}O_6$  |
|                              | CH(OH)COOH                         |                   |                    |
| 28 — thiocyanate             | $C_6H_5.CH_2.SCN$                  | 149.11            | $C_8H_7NS$         |
| 29 — iso-thiocyanate         | $C_6H_5.CH_2.NCS$                  | 149.11            | " "                |
| 30 — thiourea                | $C_6H_5.CH_2.NH.CS.NH_2$           | 166.20            | $C_8H_{10}N_2S$    |
| 31 — toluene, $m$            | $C_6H_5.CH_2.C_6H_4.CH_3$          | 182.18            | $C_{14}H_{14}$     |
| 32 — —, $p$                  | " "                                | 182.18            | " "                |
| 33 — urea                    | $C_6H_5.CH_2.NH.CO.NH_2$           | 150.14            | $C_8H_{10}ON_2$    |
| 34 Benzylidene acetone       | $C_6H_5.C_2H_5.COCH_3$             | 146.13            | $C_{10}H_{10}O$    |
| 35 — aniline                 | $C_6H_5.CHN(C_6H_5)$               | 181.16            | $C_{13}H_{11}N$    |
| 36 — bromide                 | $C_6H_5.CHBr_2$                    | 249.94            | $C_7H_6Br_2$       |
| 37 — diacetate               | $C_6H_5.CH:(CH_3COO)_2$            | 208.18            | $C_{11}H_{12}O_4$  |

| Density<br>$H_2O=1$ | Solubility in |           |             | M.P.<br>°C.  | B.P.<br>°C.   |    |
|---------------------|---------------|-----------|-------------|--------------|---------------|----|
|                     | Water.        | Alcohol.  | Ether.      |              |               |    |
|                     | i.            | s.        | s.s.        | 157          |               | 1  |
|                     |               | v.s.      | v.s.        | 54           | 283--287/650  | 2  |
|                     |               | s.        | v.s.        | 85           | 285--286/650  | 3  |
|                     |               | c.s.s.    |             | 87           |               | 4  |
|                     |               | h.s.      | s.          | 71--72       |               | 5  |
| 1.0359/16°          |               |           |             | oil          | 296           | 6  |
| 0.985/19°           | s. $CHCl_3$   | s.        | s.          |              | 294--295      | 7  |
|                     | s.            | s.        |             |              | 189           | 8  |
|                     |               |           |             |              | 135/29mm.     | 9  |
|                     |               |           |             |              | 123/50mm      | 10 |
|                     | s.            |           |             | 57           |               | 11 |
| 1.7335/25°          |               |           | s.s. $CS_2$ | 23           | d.            | 12 |
|                     | s.s.          | s.s.      | s.s.        | 120.6        |               | 13 |
| 1.058/20°           |               |           | liq.        |              | 195           | 14 |
| 1.010/3°            |               |           |             | 27           | 214           | 15 |
| 1.165/0°            |               | h. 1 : 30 | 1 : 2       | 58.6         | 350           | 16 |
| 1.176               |               | 1 : 44    | s. $C_6F_6$ | 35.5         | 350           | 17 |
|                     |               | s.        | s.          | 57           |               | 18 |
|                     |               | s.s.      | s. $C_6H_6$ | 155--156     |               | 19 |
|                     | s. alk.       | s.        |             | 84           | 320--322      | 20 |
|                     | i.            | s.        | v.s.        | 42           |               | 21 |
|                     |               |           |             |              | 276/742mm.    | 22 |
|                     |               |           |             | 34           | 287/740mm.    | 23 |
|                     | i.            | s.        | s.          | 49--50       | 170--175/13mm | 24 |
|                     |               | c.s.s.    | s. $C_6H_6$ | 150          |               | 25 |
|                     | h.s.          | s.        | s.          | 133          |               | 26 |
|                     | s.            | s.        |             | 143 d.       |               | 27 |
|                     |               |           |             |              |               |    |
|                     | i.            | v.s.      | v.s.        | 40--42       | 230--235      | 28 |
| > $H_2O$            | i.            |           |             | liq.         | 240--245      | 29 |
|                     | s.            |           |             | 103--104     |               | 30 |
| 0.997/17.5°         |               | s.        | s.          | liq.         | 268--269.5/20 | 31 |
| 0.995/17.5°         |               | s.        | s.          | - 20         | 278--280      | 32 |
|                     | h.s.          | s.        |             | 150.5--151.5 | d.            | 33 |
| 1.008               |               | s.        | s.          | 41--42       | 260--262      | 34 |
|                     | i.            | v.s.      | v.s.        | 50           | 300           | 35 |
|                     |               |           |             |              | 130--140/20   | 36 |
|                     |               | v.s.      | v.s.        | 45           | 220           | 37 |

| Name.                             | Formula.                                   | Formula Weight. | Empirical Formula. |
|-----------------------------------|--|-----------------|--------------------|
| 1 Benzylidine phthalide           | $C_6H_4 \cdot C : CH \cdot O \cdot C_6H_5$ | 222.16          | $C_{15}H_{10}O_2$  |
| 2 Berberonic acid                 | $CO-O$<br>$C_8H_7N(COOH)_3 + H_2O$         | 229.11          | $C_8H_5ON$         |
| 3 Betaine                         | $N(CH_3)_3 \cdot CH_2 \cdot COO (+H_2O)$   | 101.12          | $C_5H_{11}ON$      |
| 4 Bilirubin                       | $C_{32}H_{36}N_4O_6$                       | 572.49          | $C_{32}H_{36}ON_4$ |
| 5 Biliverdin                      | $C_{32}H_{36}N_4O_8$                       | 604.49          | $C_{32}H_{36}ON_4$ |
| 6 Bismuth tri-ethyl               | $Bi(C_2H_5)_3$                             | 296.15          | $C_6H_{15}Bi$      |
| 7 Biuret                          | $NH : (CONH_2)_2$                          | 103.08          | $C_2H_5O_2N_3$     |
| 8 Borneol                         | $C_{10}H_{18}O$                            | 154.19          | $C_{10}H_{18}O$    |
| 9 Bornyl amine                    | $C_{10}H_{17}NH_2$                         | 153.21          | $C_{10}H_{19}N$    |
| 10 — chloride                     | $C_{10}H_{17}Cl$                           | 172.65          | $C_{10}H_{17}Cl$   |
| 11 Brasileïn                      | $C_{16}H_{12}O_5$                          | 302.20          | $C_{16}H_{12}O_5$  |
| 12 Brasilin                       | $C_{16}H_{14}O_5$                          | 304.21          | $C_{16}H_{14}O_5$  |
| 13 Brassylie acid, $\alpha \beta$ | $C_9H_{18}(COOH)_2$                        | 216.22          | $C_{11}H_{20}O_4$  |
| 14 Bromo-acetamide                | $CH_3 \cdot CO \cdot NHBr$                 | 137.97          | $C_2H_4ONBr$       |
| 15 — acetanilide, <i>o</i>        | $Br \cdot C_6H_4 \cdot NH \cdot COCH_3$    | 214.03          | $C_8H_8ONBr$       |
| 16 — —, <i>m</i>                  | " "  | 214.03          | "                  |
| 17 — —, <i>p</i>                  | " "  | 214.03          | "                  |
| 18 — acetic acid                  | $CH_2Br \cdot COOH$                        | 138.95          | $C_2H_3O_2Br$      |
| 19 — acetate, ethyl               | $CH_2Br \cdot COOC_2H_5$                   | 167.00          | $C_4H_7O_2Br$      |
| 20 — acetophenone                 | $C_6H_5 \cdot CO \cdot CH_2Br$             | 199.02          | $C_8H_7OBr$        |
| 21 — acetotoluide, 5 : 2          | $Br \cdot C_7H_6 \cdot NH \cdot COCH_3$    | 228.05          | $C_9H_{10}ONBr$    |
| 22 — —, 3 : 4                     | " "  | 228.05          | "                  |
| 23 — acetyl bromide               | $CH_2Br \cdot CO \cdot Br$                 | 201.87          | $C_2H_2OBr_2$      |
| 24 — — chloride                   | $CH_2Br \cdot COCl$                        | 157.41          | $C_2H_2OClBr$      |
| 25 — acetylene                    | $C_2HBr$                                   | 104.94          | $C_2HBr$           |
| 26 — allyl alcohol                | $CH_2 : CBr \cdot CH_2OH$                  | 136.98          | $C_3H_5OBr$        |
| 27 — aniline, <i>o</i>            | $Br \cdot C_6H_4 \cdot NH_2$               | 172.01          | $C_6H_5NBr$        |
| 28 — —, <i>m</i>                  | " "  | 172.01          | "                  |
| 29 — —, <i>p</i>                  | " "  | 172.01          | "                  |
| 30 — anthraquinone, 1             | $C_6H_4 : (CO)_2 : C_6H_3Br$               | 287.05          | $C_{14}H_7O_2Br$   |
| 31 — —, 2                         | " "  | 287.05          | "                  |
| 32 — benzene                      | $C_6H_5 \cdot Br$                          | 156.09          | $C_6H_5Br$         |
| 33 — benzoic acid, <i>o</i>       | $Br \cdot C_6H_4 \cdot COOH$               | 201.00          | $C_7H_5O_2Br$      |
| 34 — — —, <i>m</i>                | " "  | 201.00          | "                  |
| 35 — — —, <i>p</i>                | " "  | 201.00          | "                  |
| 36 — butyric acid, $\alpha$       | $CH_3 \cdot CH_2 \cdot CHBr \cdot COOH$    | 167.00          | $C_4H_7O_2Br$      |
| 37 — iso-butyric acid, $\alpha$   | $(CH_3)_2 : CBr \cdot COOH$                | 167.00          | "                  |



| Density<br>$H_2O=1$ . | Solubility in     |          |                | M.P.<br>°C. | B.P.<br>°C.      |    |
|-----------------------|-------------------|----------|----------------|-------------|------------------|----|
|                       | Water.            | Alcohol. | Ether.         |             |                  |    |
|                       |                   | h.s.     |                | 99, 180 91  |                  | 1  |
|                       | h.s.              | h.s.s.   | i.             | 235         |                  | 2  |
|                       | 61.8: 100<br>/25° | s.       | i.             |             |                  | 3  |
|                       | i.                | v.s.s.   | v.s.s.         | 192—192.5   |                  | 4  |
|                       | i.                | s.       | s.s.           |             |                  | 5  |
| 3/18°                 | i.                | s.       | s.             | liq.        | 10.              | 6  |
|                       | s.                | s.       |                | 190 d.      |                  | 7  |
| .011                  | i.                | s.       | s.             | 205         | 212              | 8  |
|                       | s.s.              | v.s.     | v.s.           | 159—160     |                  | 9  |
|                       | d. 40°            | v.s.     | v.s.           | 158         |                  | 10 |
|                       | s. alk.           | s.       |                |             |                  | 11 |
|                       | s.                | s.       | s.             |             |                  | 12 |
|                       | s.s.              |          |                | 90—91       |                  | 13 |
|                       | s.                | s        | i.             | 91          |                  | 14 |
|                       |                   | s.       |                | 99          |                  | 15 |
|                       |                   | s.s.     | s.s.           | 84          |                  | 16 |
|                       | c.i               | s.s.     |                | 168         |                  | 17 |
|                       | W.                |          |                | 49—50       | 208              | 18 |
|                       |                   |          |                |             | 159              | 19 |
|                       |                   | v.s.     | v.s.           | 51          |                  | 20 |
|                       |                   |          |                | 156—157     |                  | 21 |
|                       |                   |          |                | 117         |                  | 22 |
| .317/21.5°            |                   |          |                |             | 149—150          | 23 |
| .908/0°               |                   |          |                |             | 127—127.5        | 24 |
|                       |                   |          |                | gas         |                  | 25 |
| .6/15°                |                   |          |                |             | 155              | 26 |
|                       |                   | s.       |                | 31—31.5     | 250—251          | 27 |
|                       |                   | s.       |                | 18—18.5     | 251              | 28 |
|                       |                   | s.       |                | 66.4        | d.               | 29 |
|                       |                   | s.       |                | 204—205     | subl.            | 30 |
|                       | s.p.              |          | s.h. $O_2 H_6$ | 188         | subl.            | 31 |
| .495/16°              |                   | s.       |                | — 31.1      | 156.15           | 32 |
| .929/20°              | s.                | v.s.     | v.s.           | 150         |                  | 33 |
| .845/20°              | s.s.              | v.s.     | v.s.           | 155         | >280             | 34 |
| .894/20°              | v.s.s.            | v.s.     | v.s.           | 251         |                  | 35 |
| .54/15°               | 1:15              |          |                | 81          | 137—137.5/50 mm. | 36 |
|                       |                   |          |                | 29          | 198—200          | 37 |

| Name.                          | Formula.                 | Formula Empirical Weight. | Formula.          |
|--------------------------------|--------------------------|---------------------------|-------------------|
| 1 Bromo camphor                | $C_{10}H_{15}OBr$        | 231.09                    | $C_{10}H_{15}OBr$ |
| 2 — cinnamic acid, $\alpha$    | $C_6H_5.CH:CH.CO_2H$     | 227.02                    | $C_9H_7O_2Br$     |
| 3 — —, $\beta$                 | $C_6H_5.CBr:CH.CO_2H$    | 227.02                    | "                 |
| 4 — ethylene                   | $CH_2:CHBr$              | 106.95                    | $C_2H_3Br$        |
| 5 — hexahydrobenzene           | $C_6H_5.Br(H)_6$         | 163.04                    | $C_6H_3Br$        |
| 6 — naphthalene, $\alpha$      | $C_{10}H_7Br$            | 207.03                    | $C_{10}H_7Br$     |
| 7 — —, $\beta$                 | " "                      | 207.03                    | "                 |
| 8 — nitro benzene, $o$         | $Br.C_6H_4.NO_2$         | 201.99                    | $C_6H_4O_2NBr$    |
| 9 — — —, $m$                   | " "                      | 201.99                    | "                 |
| 10 — — —, $p$                  | " "                      | 201.99                    | "                 |
| 11 — phenol, $o$               | $Br.C_6H_4OH$            | 172.99                    | $C_6H_5OBr$       |
| 12 — —, $m$                    | " "                      | 172.99                    | "                 |
| 13 — —, $p$                    | " "                      | 172.99                    | "                 |
| 14 — phenyl hydrazine, $p$     | $Br.C_6H_4.NH.NH_2$      | 187.02                    | $C_6H_7N_2Br$     |
| 15 — phthalic acid, $5$        | $Br.C_6H_3:(COOH)_2$     | 242.00                    | $C_8H_5O_2Br$     |
| 16 — propionic acid, $\alpha$  | $CH_3.CHBr.CO_2H$        | 152.98                    | $C_3H_5O_2Br$     |
| 17 — styrol, $\alpha$          | $C_6H_5.CH:CHBr$         | 183.02                    | $C_8H_7Br$        |
| 18 — —, $\beta$                | $C_6H_5.CBr:CH_2$        | 183.02                    | "                 |
| 19 — succinic acid             | $COOH.CHBr.CH_2.CO_2H$   | 196.98                    | $CH_2O_2Br$       |
| 20 — toluene, $o$              | $CH_3.C_6H_4.Br$         | 171.01                    | $C_7H_7Br$        |
| 21 — —, $m$                    | " "                      | 171.01                    | "                 |
| 22 — —, $p$                    | " "                      | 171.01                    | "                 |
| 23 — toluidine,                | $CH_3.C_6H_3(Br)NH_2$    | 186.03                    | $C_7H_7NBr$       |
|                                | $NH_2:Br=2:5$            |                           |                   |
| 24 — —,                        | $3:6$                    | 186.03                    | "                 |
| 25 — —,                        | $4:3$                    | 186.03                    | "                 |
| 26 — <i>iso</i> -valeric acid  | $(CH_3)_2:CH.CHBr.CO_2H$ | 181.02                    | $C_8H_{11}O_2Br$  |
| 27 Bromal                      | $CBr_3.CO_2H$            | 280.78                    | $C_2H_2OBr_3$     |
| 28 Bromoform                   | $CHBr_3$                 | 252.77                    | $CHBr_3$          |
| 29 Butane, <i>norm.</i>        | $CH_3.CH_2.CH_2.CH_3$    | 58.10                     | $C_4H_{10}$       |
| 30 —, trimethylmethane         | $CH(CH_3)_3$             | 58.10                     | "                 |
| 31 Butyl alcohol, <i>norm.</i> | $CH_3.CH_2.CH_2.CH_2OH$  | 74.10                     | $C_4H_{10}O$      |
| 32 — —, <i>iso.</i>            | $(CH_3)_2:CH.CH_2OH$     | 74.10                     | "                 |
| 33 — —, ethyl methyl carbinol  | $C_2H_5.CHOH.CH_3$       | 74.10                     | "                 |
| 34 — —, trimethyl carbinol     | $(CH_3)_3COH$            | 74.10                     | "                 |
| 35 — amine, <i>norm</i>        | $C_4H_9.NH_2$            | 73.12                     | $C_4H_{11}N$      |
| 36 — —, <i>sec.</i>            | $CH_3.CH(NH_2)CH_2.CH_3$ | 73.12                     | "                 |
| 37 — benzene, <i>norm.</i>     | $C_6H_5.C_6H_5$          | 134.16                    | $C_{10}H_{14}$    |

| Density<br>$H_2O=1$ . | Solubility in |             |             | M.P.<br>°C. | B.P.<br>°C.    |    |
|-----------------------|---------------|-------------|-------------|-------------|----------------|----|
|                       | Water.        | Alcohol.    | Ether.      |             |                |    |
| 1.437                 | s. $C_6H_6$   | s.s.        | s. $CS_2$   | 76          | 274            | 1  |
|                       |               | m.          | m.          | 130—131     |                | 2  |
|                       | h.s.          | v.s.        | v.s. $CS_2$ | 120         |                | 3  |
| 1.53/11°              |               |             | liq.        |             | 16/750mm.      | 4  |
|                       |               |             |             |             | 162—163/714 d. | 5  |
| 1.488/16°             | m. $C_6H_6$   | m. (abs.)   | m.          | liq.        | 277            | 6  |
| 1.605/0°              | s. $C_6H_6$   | v.s.        | v.s.        | 59          | 281—282        | 7  |
|                       |               | s. oleum.   |             | 41          | 261            | 8  |
|                       | v.s.s.        | s.s.        |             | 54          | 256.5          | 9  |
|                       |               | i. oleum.   |             | 126         | 255—256        | 10 |
|                       |               |             |             | S.P. 5.6    | 194—195        | 11 |
|                       |               |             |             | 32—33       | 236—236.5      | 12 |
| 1.840/15°             | s. $CHCl_3$   | v.s.        | v.s.        | 63.5        | 238            | 13 |
|                       |               |             |             | 107         |                | 14 |
|                       | v.s.          | v.s.        | v.s.        | 138—40      |                | 15 |
|                       |               |             |             | 25.7—27.1   | 205.5 (corr.)  | 16 |
|                       |               |             |             |             | 150—160/75     | 17 |
|                       |               |             |             | 7           | 219—221        | 18 |
|                       | 1:5.2/15°     |             |             | 159         |                | 19 |
| 1.4222/20°            |               |             |             | —25.9       | 180.3/754      | 20 |
| 1.4099/20°            |               | s.          |             | —39.8       | 183.7          | 21 |
| 1.3898/20°            |               | s.          | s.          | 26.5        | 183.6/758      | 22 |
|                       |               |             |             | 58—59       | 240            | 23 |
|                       |               |             |             | 78.4—78.8   | 240            | 24 |
| 1.510/20°             |               |             |             | 26          | 240            | 25 |
|                       | s.s.          |             |             | 44          | 230 d.         | 26 |
| 3.34                  | d.            |             |             | liq.        | 172.5—173      | 27 |
| 2.9045/15°            | i.            |             |             | 7.8         | 146.5/757.5    | 28 |
|                       | i.            | 18 vol. : 1 |             | —135        | 0.6            | 29 |
| 0.6                   |               |             |             | —145        | —10.2          | 30 |
| 0.8094/0°             | 1:12          |             | s. $HCl$    | liq.        | 116.9          | 31 |
| 0.8057/15°            | 1:10.5/18°    |             |             | liq.        | 107.4          | 32 |
| 0.819/22°             | s.            |             |             | liq.        | 101/745mm      | 33 |
| 0.7887/20°            | m.            |             |             | 25          | 82.9           | 34 |
| 0.7401/20°            | m.            | s.          | s.          | liq.        | 75.5           | 35 |
| 0.7557/15°            | m.            |             |             | liq.        | 63             | 36 |
| 0.875/0°              |               |             |             |             | 186            | 37 |

| Name.                           | Formula.                   | Formula Empirical<br>Weight. Formula. |
|---------------------------------|----------------------------|---------------------------------------|
| 1 Butyl benzene, <i>iso</i> .   | $C_6H_5.C_4H_9$            | 134.16 $C_{10}H_{14}$                 |
| 2 —, <i>sec</i> .               | " "                        | 134.16 "                              |
| 3 — choral                      | $C_4H_5Cl_3O$              | 175.44 $C_4H_5OCl_3$                  |
| 4 — hydrate                     | $C_4H_5Cl_3O.H_2O$         | 193.46 $C_4H_5O_2Cl_3$                |
| 5 — chloride, <i>norm</i> .     | $CH_3.CH_2.CH_2.CH_2Cl$    | 92.55 $C_4H_9Cl$                      |
| 6 —, <i>iso</i> .               | $(CH_3)_2:CH.CH_2Cl$       | 92.55 "                               |
| 7 —, <i>tert</i> .              | $(CH_3)_3CCl$              | 92.55 "                               |
| 8 — cyanide, <i>norm</i> .      | $CH_3.CH_2.CH_2.CH_2CN$    | 83.11 $C_5H_9N$                       |
| 9 —, <i>iso</i> .               | $(CH_3)_2:CH.CH_2CN$       | 83.11 "                               |
| 10 —, <i>tert</i> .             | $(CH_3)_3C.CN$             | 83.11 "                               |
| 11 — ether                      | $(O.H)_2:O$                | 130.18 $C_8H_{18}O$                   |
| 12 — ethyl ether                | $C_4H_9.O.C_2H_5$          | 102.14 $C_6H_{14}O$                   |
| 13 — iodide, <i>norm</i> .      | $CH_3.CH_2.CH_2.CH_2I$     | 184.01 $C_4H_9I$                      |
| 14 —, <i>iso</i> .              | $(CH_3)_2:CH.CH_2I$        | 184.01 "                              |
| 15 —, <i>sec</i> .              | $CH_3.CH_2.CH(CH_3)I$      | 184.01 "                              |
| 16 —, <i>tert</i> .             | $(CH_3)_3CI$               | 184.01 "                              |
| 17 — mercaptan                  | $C_4H_9SH$                 | 90.16 $C_4H_{10}S$                    |
| 18 — sulphide, <i>norm</i> .    | $(CH_3.CH_2.CH_2.CH_2)_2S$ | 146.24 $C_8H_{18}S$                   |
| 19 —, <i>sec</i> .              | $(CH_3.CH_2.CH(CH_3))_2S$  | 146.24 "                              |
| 20 — thiocyanate, <i>norm</i> . | $CH_3.CH_2.CH_2.CH_2.NCS$  | 115.17 $C_5H_9NS$                     |
| 21 —, <i>iso</i> .              | $(CH_3)_2:CH.CH_2.NCS$     | 115.17 "                              |
| 22 —, <i>sec</i> .              | $CH_3.CH_2.CH(NCS)CH_3$    | 115.17 "                              |
| 23 —, <i>tert</i> .             | $(CH_3)_3C.NCS$            | 115.17 "                              |
| 24 Butylene, <i>norm</i> .      | $CH_3CH_2.CH:CH_2$         | 56.08 $C_4H_8$                        |
| 25 —, <i>iso</i> .              | $(CH_3)_2:C:CH_2$          | 56.08 "                               |
| 26 —, <i>pseudo</i> .           | $CH_3.CH:CH.CH_3$          | 56.08 "                               |
| 27 — bromide, $\beta$           | $CH_3CHBr.CHBr.CH_3$       | 215.92 $C_4H_8Br_2$                   |
| 28 — glycol, <i>norm</i> .      | $CH_3.CH_2.CHOH.CH_2OH$    | 90.10 $C_4H_{10}O_2$                  |
| 29 —, $\beta$                   | $CH_3.CHOH.CH_2.CH_2OH$    | 90.10 "                               |
| 30 —, <i>iso</i> .              | $(CH_3)_2:COH.CH_2OH$      | 90.10 "                               |
| 31 Butyramide, <i>norm</i> .    | $CH_3.CH_2.CH_2.CONH_2$    | 87.10 $C_4H_9ON$                      |
| 32 —, <i>iso</i> .              | $(CH_3)_2:CH.CONH_2$       | 87.10 "                               |
| 33 Butyric acid, <i>norm</i> .  | $CH_3.CH_2.CH_2.COOH$      | 88.08 $C_4H_8O_2$                     |
| 34 —, <i>iso</i> .              | $(CH_3)_2:CH.COOH$         | 88.08 "                               |
| 35 Butyrate, amyl               | $C_5H_7.COO.C_5H_{11}$     | 158.19 $C_9H_{18}O_2$                 |
| 36 —, ethyl                     | $C_5H_7.COOC_2H_5$         | 116.13 $C_6H_{12}O_2$                 |
| 37 —, <i>iso</i> .              | $(CH_3)_2:CH.COOC_2H_5$    | 116.13 "                              |
| 38 — methyl                     | $C_5H_7.COOCH_3$           | 102.11 $C_5H_{10}O_2$                 |
| 39 —, <i>iso</i> .              | $(CH_3)_2:CH.COOCH_3$      | 102.11 "                              |

| Density<br>$H_2O=1$ . | Solubility in |          |        | M.P.<br>°C. | B.P.<br>°C.    |    |
|-----------------------|---------------|----------|--------|-------------|----------------|----|
|                       | Water.        | Alcohol. | Ether. |             |                |    |
| 0.8578/15°            |               |          |        |             | 167.5          | 1  |
| 0.8726/16°            |               |          |        |             | 170—172        | 2  |
| 1.395/20°             | d.            |          |        | liq.        | 164—165/750    | 3  |
| 1.693                 | h.s.          | v.s.     |        | 78          | d.             | 4  |
| 0.8874/20°            |               |          |        | liq.        | 77.96          | 5  |
| 0.8336/15°            |               |          |        | liq.        | 68.5           | 6  |
| 0.847/15°             |               |          |        | liq.        | 51—52          | 7  |
| 0.816/0°              |               |          |        | liq.        | 140.4/739      | 8  |
| 0.8227/0°             | s.s.          |          |        | liq.        | 129.3          | 9  |
|                       |               |          |        | 15—16       | 105—106        | 10 |
| 0.7685/20°            |               |          |        | liq.        | 140.5          | 11 |
| 0.7522/2°             |               |          |        |             | 91.7           | 12 |
| 1.6166/20°            |               |          |        | liq.        | 131.4/745.4    | 13 |
| 1.6401/0°             |               |          |        | liq.        | 120/745.4      | 14 |
| 1.6263/0°             |               |          |        | liq.        | 118            | 15 |
| 1.571/0°              | d.            |          |        | liq.        | 98—99          | 16 |
| 0.858/0°              |               |          |        | liq.        | 92             | 17 |
| 0.8523/0°             | j.            |          |        | liq.        | 182            | 18 |
| 0.8317/23°            |               |          |        | liq.        | 165            | 19 |
|                       |               |          |        | liq.        | 167            | 20 |
| 0.9638/14°            |               |          |        | liq.        | 162            | 21 |
| 0.944/12°             |               |          |        | liq.        | 159.5          | 22 |
| 0.9187/10°            |               |          |        | 10.5        | 140            | 23 |
|                       |               |          |        |             | -5             | 24 |
|                       | s. $H_2SO_4$  |          |        |             | -6             | 25 |
| 0.635/-13°            | i. $H_2SO_4$  |          |        |             | +1/741.4 mm    | 26 |
| 1.821/0°              |               |          |        |             | 158            | 27 |
| 1.019/0°              | v.s.          | m.       |        | liq.        | 191—192/747 mm | 28 |
| 1.0259                | v.s.          | s.       | i.     | liq.        | 203.5—204      | 29 |
| 1.0129/0°             | s.            |          |        | liq.        | 176—178        | 30 |
|                       | v.s.          | s.       | s.     | 116         | 216            | 31 |
|                       | v.s.          | s.       | s.s.   | 127.5       | 216—220        | 32 |
| 0.9746/0°             | m.            | m.       | m.     | -8          | 162.3          | 33 |
| 0.9487/19.8°          | 1:5           |          |        | -79         | 155.5          | 34 |
| 0.8832                | s.s.          | v.s.     | v.s.   | liq.        | 178.6          | 35 |
| 0.8807/18°            | 0.5:100       | s.       | s.     | -80         | 119.9          | 36 |
| 0.8710/20°            | i.            | s.       |        | -116        | 110.1          | 37 |
| 0.9194/0°             |               | s.       |        | liq.        | 102—102.5      | 38 |
| 0.911/0°              |               | s.       | s.     | liq.        | 92.4           | 39 |

| Name.                            | Formula   | Formula Weight. | Empirical Formula.                         |
|----------------------------------|---|-----------------|--|
| 1 Butyric aldehyde, <i>norm</i>  | $\text{CH}_3.\text{CH}_2.\text{CH}_2.\text{CHO}$                | 72.08           | $\text{C}_4\text{H}_8\text{O}$             |
| 2 —, <i>iso</i> .                | $(\text{CH}_3)_2:\text{CH}.\text{CHO}$                          | 72.08           | "  |
| 3 — anhydride, <i>norm</i> .     | $(\text{C}_4\text{H}_7\text{O})_2:\text{O}$                     | 158.15          | $\text{C}_8\text{H}_{14}\text{O}_3$        |
| 4 Butyrolactone, $\gamma$        | $\text{C}_4\text{H}_7\text{O}_2$                                | 86.07           | $\text{C}_4\text{H}_6\text{O}_2$           |
| 5 Butyrene                       | $(\text{C}_4\text{H}_7)_2\text{CO}$                             | 114.15          | $\text{C}_7\text{H}_{14}\text{O}$          |
| 6 Butyryl chloride, <i>norm</i>  | $\text{CH}_3.\text{CH}_2.\text{CH}_2.\text{COCl}$               | 106.54          | $\text{C}_4\text{H}_7\text{OCl}$           |
| 7 —, <i>iso</i> .                | $(\text{CH}_3)_2:\text{CH}.\text{COCl}$                         | 106.54          | "  |
| 8 Cacodyl                        | $(\text{CH}_3)_2\text{As}(\text{CH}_3)_2$                       | 210.04          | $\text{C}_4\text{H}_{12}\text{As}_2$       |
| 9 — chloride                     | $(\text{CH}_3)_2\text{AsCl}$                                    | 140.48          | $\text{C}_2\text{H}_6\text{ClAs}$          |
| 10 — oxide                       | $[(\text{CH}_3)_2\text{As}]_2\text{O}$                          | 226.04          | $\text{C}_4\text{H}_{12}\text{OAs}_2$      |
| 11 — sulphide                    | $[(\text{CH}_3)_2\text{As}]_2\text{S}$                          | 242.10          | $\text{C}_4\text{H}_{12}\text{SAs}_2$      |
| 12 — trichloride                 | $(\text{CH}_3)_2\text{AsCl}_3$                                  | 211.40          | $\text{C}_2\text{H}_6\text{Cl}_3\text{As}$ |
| 13 Cacodylic acid                | $(\text{CH}_3)_2\text{AsO}.\text{OH}$                           | 138.03          | $\text{C}_2\text{H}_7\text{O}_2\text{As}$  |
| 14 Cadaverine, see               | Pentamethylene diamine  |                 |  |
| 15 Camphane                      | $\text{C}_{10}\text{H}_{18}$                                    | 138.19          | $\text{C}_{10}\text{H}_{18}$               |
| 16 Camphene, l.                  | $\text{C}_{10}\text{H}_{16}$                                    | 136.18          | $\text{C}_{10}\text{H}_{16}$               |
| 17 —, d.                         | "   | 136.18          | "  |
| 18 Campholenic acid, d.          | $\text{C}_{10}\text{H}_{18}\text{O}_2$                          | 170.19          | $\text{C}_{10}\text{H}_{18}\text{O}_2$     |
| 19 Camphor, l.                   | $\text{C}_{10}\text{H}_{16}\text{O}$                            | 152.18          | $\text{C}_{10}\text{H}_{16}\text{O}$       |
| 20 —, d.                         | "   | 152.18          | "  |
| 21 Camphoric acid                | $\text{C}_5\text{H}_5(\text{CH}_3)_3(\text{COOH})_2$            | 200.18          | $\text{C}_{10}\text{H}_{16}\text{O}_4$     |
| 22 Camphoronic acid, d.          | $\text{C}_9\text{H}_{14}\text{O}_6$                             | 218.16          | $\text{C}_9\text{H}_{14}\text{O}_6$        |
| 23 Camphor oxime, l.             | $\text{C}_{10}\text{H}_{16}:\text{NOH}$                         | 167.20          | $\text{C}_{10}\text{H}_{17}\text{ON}$      |
| 24 Camphylamine                  | $\text{C}_9\text{H}_{15}.\text{CH}_2.\text{NH}_2$               | 153.21          | $\text{C}_{10}\text{H}_{19}\text{N}$       |
| 25 Cane sugar, sucrose           | $\text{C}_{12}\text{H}_{22}\text{O}_{11}$                       | 342.24          | $\text{C}_{12}\text{H}_{22}\text{O}_{11}$  |
| 26 Cantharidin                   | $\text{C}_{10}\text{H}_{12}\text{O}_4$                          | 196.14          | $\text{C}_{10}\text{H}_{12}\text{O}_4$     |
| 27 Capric acid                   | $\text{C}_9\text{H}_{19}\text{COOH}$                            | 172.21          | $\text{C}_{10}\text{H}_{20}\text{O}_2$     |
| 28 Caprate, ethyl                | $\text{C}_9\text{H}_{19}.\text{COOC}_2\text{H}_5$               | 200.25          | $\text{C}_{12}\text{H}_{24}\text{O}_2$     |
| 29 Caproic acid, <i>norm</i> .   | $\text{C}_5\text{H}_{11}\text{COOH}$                            | 116.13          | $\text{C}_6\text{H}_{12}\text{O}_2$        |
| 30 —, <i>iso</i> .               | $(\text{CH}_3)_2:\text{CH}.\text{CH}_2.\text{CH}_2.\text{COOH}$ | 116.13          | "  |
| 31 —, diethyl acetic acid        | $(\text{C}_2\text{H}_5)_2:\text{CH}.\text{COOH}$                | 116.13          | "  |
| 32 —, dimethyl ethyl acetic acid | $(\text{CH}_3)_2(\text{C}_2\text{H}_5)\text{C}.\text{COOH}$     | 116.13          | "  |
| 33 Capronate, ethyl              | $\text{C}_5\text{H}_{11}.\text{COOC}_2\text{H}_5$               | 144.17          | $\text{C}_8\text{H}_{16}\text{O}_2$        |
| 34 Capronitrile                  | $\text{C}_5\text{H}_{11}\text{CN}$                              | 97.13           | $\text{C}_6\text{H}_{11}\text{N}$          |
| 35 Caprylic acid                 | $\text{C}_7\text{H}_{15}\text{COOH}$                            | 144.17          | $\text{C}_8\text{H}_{16}\text{O}_2$        |
| 36 Caprylate, ethyl              | $\text{C}_7\text{H}_{15}.\text{COOC}_2\text{H}_5$               | 172.21          | $\text{C}_{10}\text{H}_{20}\text{O}_2$     |
| 37 Carbamide chloride            | $\text{CO}(\text{NH}_2)\text{Cl}$                               | 74.09           | $\text{CH}_2\text{ONCl}$                   |
| 38 Carbamidine, see              | Guanidine   |                 |  |

| Density<br>H <sub>2</sub> O=1. | Solubility in |             |           | M.P.<br>°C. | B.P.<br>°C.     |    |
|--------------------------------|---------------|-------------|-----------|-------------|-----------------|----|
|                                | Water.        | Alcohol.    | Ether.    |             |                 |    |
| 0.8170/20°                     | 1: 27         |             |           | liq.        | 73—74           | 1  |
| 0.7938/20°                     | 1: 9/20°      |             |           | liq.        | 63/741mm.       | 2  |
| 0.978/15.5°                    |               |             |           | liq.        | 191—193         | 3  |
| 1.1441/0°                      | m.            | s.s.        | s.s.      |             | 203.5—204       | 4  |
| 0.82/20°                       | i.            |             |           | liq.        | 142             | 5  |
| 1.0277/20°                     |               |             |           | liq.        | 99—101/734.4    | 6  |
| 1.0174/20°                     |               |             |           | liq.        | 91.5—92.5/748.2 | 7  |
| >H <sub>2</sub> O              | s.s.          | s.          | s.        | -6          | 170             | 8  |
| >H <sub>2</sub> O              | i.            |             |           | liq.        | 100             | 9  |
| 1.462                          | s.s.          |             |           | -25         | 120             | 10 |
|                                | s.            | s.          |           |             | 211             | 11 |
|                                | d.            |             |           |             |                 | 12 |
|                                | v.s.          | s.          |           |             | 200             | 13 |
|                                |               |             |           |             |                 | 14 |
|                                |               |             |           | 158—159     | 160—161/763     | 15 |
| 0.879/60°                      |               |             |           | 51—52       | 158.5—159.5     | 16 |
|                                |               |             |           | 50—51       | 158—159         | 17 |
|                                | s. oils       | 1: 0.8      | v.s.      | 95          | 250             | 18 |
| 0.992/10°                      | s.s. acetic   | s.          | s.        | 172         | 204/757mm.      | 19 |
|                                |               |             |           | 176.4       | 209.1           | 20 |
| 1.193                          | h. 1: 12      | c. 1: 0.89  |           | 187 (corr.) | d.              | 21 |
|                                | s.            | s.          | s.s.      | 158—159 d.  |                 | 22 |
|                                |               | v.s.        | v.s.      | 115         | d. 250          | 23 |
| 0.93/37°                       |               |             |           |             | 194—196         | 24 |
| 1.5881/20°                     | 190:100/10°   | s.s.        |           | 160         | d.              | 25 |
|                                | i.            | c. 0.03:100 | 0.11: 100 | 218         |                 | 26 |
| 0.930/27°                      | h.s.s.        | s.          | s.        | 31          | 266—268         | 27 |
| 0.862                          |               |             |           | liq.        | 243—245         | 28 |
| 0.929/20°                      | s.s.          |             |           | -1.5        | 205             | 29 |
| 0.9237/20°                     | s.s.          |             |           |             | 199.7           | 30 |
| 0.9196/15°                     | s.s.          |             |           | liq.        | 190.1           | 31 |
|                                | i.            |             |           | -14         | 187             | 32 |
| 0.8728/20°                     | i.            | s.          | m.        | liq.        | 214             | 33 |
| 0.866/20°                      | s.s.          | m           | s.        | liq.        | 144—146         | 34 |
| 0.9270/0°                      | 1:400/100°    | m.          | m.        | 16.5        | 232—234         | 25 |
| 0.8730/16°                     | d.            |             |           | liq.        | 205.8           | 36 |
|                                | i.            | i.          |           | 50          | 61—62           | 37 |
|                                |               |             |           |             |                 | 38 |

| Name.   | Formula.  | Formula Weight. | Empirical Formula.   |
|---|---|-----------------|----------------------|
| 1 Carbanile                                     | $C_6H_5.N:CO$   | 119.09          | $C_7H_5ON$           |
| 2 Carbanilide                                   | $CO:(NH.C_6H_5)_2$  | 212.18          | $C_{13}H_{12}ON_2$   |
| 3 Carbazide                                     | $CO:(NH.NH_2)_2$  | 90.09           | $CH_3ON$             |
| 4 Carbazole                                     | $(C_6H_4)_2:NH$   | 167.15          | $C_{12}H_9N$         |
| 5 Carbodiphenylimide, $\alpha$                  | $C_6H_5.N:C:N.C_6H_5$   | 194.11          | $C_{13}H_{10}N_2$    |
| 6 —, $\beta$                                    | " "   | 194.11          | "                    |
| 7 —, $\gamma$                                   | " "   | 194.11          | "                    |
| 8 Carbon tetrachloride                          | $CCl_4$   | 153.84          | $CCl_4$              |
| 9 Carbostyryl                                   | $C_6H_4 \begin{matrix} \diagup NH \\ \diagdown C_2H_2 \end{matrix} CO$                      | 145.11          | $C_9H_7ON$           |
| 10 Carboxy phenyl thio-glycollic acid, $\alpha$ | $C_6H_4.(COOH).(S.CH_2.COOH)$   | 212.17          | $C_9H_8O_4S$         |
| 11 Carbyl sulphate                              | $CH_2.O.SO_2.O.SO_2.CH_2$   | 188.16          | $C_2H_4O_6S_2$       |
| 12 Carminic acid                                | $C_{17}H_{18}O_{10}$  | 382.23          | $C_{17}H_{18}O_{10}$ |
| 13 Carnine                                      | $C_{17}H_{18}O_4.H_2O$  | 182.16          | $C_{17}H_{18}ON^4$   |
| 14 Carvacrol, 5:2:1                             | $C_6H_3(C_3H_7)_2(CH_3)OH$  | 150.16          | $C_{10}H_{14}O^4$    |
| 15 Carvenone                                    | $CH_3.CH \begin{matrix} \diagup CH_2.CH_2 \\ \diagdown CO.CH \\ C.CH:(CH_3)_2 \end{matrix}$ | 152.18          | $C_{10}H_{16}O$      |
| 16 Carvoménthene                                | $C_{10}H_{18}$  | 138.19          | $C_{10}H_{18}$       |
| 17 Carvoménthol                                 | $C_{10}H_{19}OH$  | 156.21          | $C_{10}H_{20}O$      |
| 18 Carvone, d.                                  | $CH_3.C \begin{matrix} \diagup CH.CH_2 \\ \diagdown CO.CH_2 \end{matrix} CH_3$              | 150.16          | $C_{10}H_{14}O$      |
| 19 Caryophyllene                                | $C_{15}H_{24}$  | 204.27          | $C_{15}H_{24}$       |
| 20 Catechin                                     | $C_{15}H_{14}O_6$   | 290.19          | $C_{15}H_{14}O_6$    |
| 21 Cedrene                                      | $C_{15}H_{24}$  | 204.27          | $C_{15}H_{24}$       |
| 22 Cellulose                                    | $(C_6H_{10}O_5)_x$  | (162.11)        |                      |
| 23 Cerotic acid                                 | $C_{26}H_{52}O_2$   | 296.55          | $C_{26}H_{52}O_2$    |
| 24 Ceryl alcohol                                | $C_{26}H_{54}O$   | 382.56          | $C_{26}H_{54}O$      |
| 25 Cetyl alcohol                                | $C_{18}H_{34}O$   | 242.35          | $C_{16}H_{34}O$      |
| 26 Cetylene                                     | $C_{16}H_{32}$  | 224.34          | $C_{16}H_{32}$       |
| 27 Chelidonic acid                              | $C_5H_2O_2(COOH)_2$   | 184.67          | $C_7H_4O_6$          |
| 28 Chinophenol, see                             | Hydroxy quinoline   |                 |                      |



| Density<br>H <sub>2</sub> O=1. | Solubility in |              |        | M.P.<br>°C | B.P.<br>°C.  |    |
|--------------------------------|---------------|--------------|--------|------------|--------------|----|
|                                | Water.        | Alcohol.     | Ether. |            |              |    |
| 1.092/15°                      | d.            |              |        | liq.       | 166          | 1  |
|                                | s.s.          | s.           | s.     | 239—240    |              | 2  |
|                                |               |              |        | 152—153    |              | 3  |
|                                | i.            | 0.92:100/14° | s.     | subl. 238  | 338          | 4  |
|                                |               | h.d.         | d.     |            | 163—165/11mm | 5  |
|                                |               |              |        | 158—160    | 235—236/65mm | 6  |
|                                |               |              |        | 96—98      |              | 7  |
| 1.582/21°                      | i.            |              |        | —23.8      | 76.7         | 8  |
|                                | h.s.          | v.s.         | v.s.   | 199—200    | subl.        | 9  |
|                                |               |              |        | 212—214    |              | 10 |
|                                | del. d.       |              |        | 80         |              | 11 |
|                                | v.s.          | s            | s.s.   |            |              | 12 |
|                                | h.s.          | i            | i.     |            |              | 13 |
| 0.9856/15°                     |               | s            |        | 0          | 236—237      | 14 |
| 0.927                          |               |              |        |            | 235.5—236    | 15 |
| 0.8230/16.5°                   |               |              |        |            | 174—175      | 16 |
| 0.908/20°                      |               |              |        |            | 220          | 17 |
| 0.953/15°                      |               |              |        | liq.       | 227—228      | 18 |
|                                |               |              |        |            |              |    |
|                                | i.            | s.s.         |        | 258—260    | subl. 280    | 19 |
|                                | h.s.          | s.           | s.     | 235—237    | d.           | 20 |
| 0.9359/15°                     |               |              |        | liq.       | 237          | 21 |
|                                | s. oupram.    |              |        |            |              | 22 |
|                                | i.            | i.           | i.     | 76—77      | d.           | 23 |
|                                | i.            | s.           | s.     | 79         | 305/20mm.    | 24 |
| 0.8176/49°                     | i.            | s.           | s.     | 50—51      | 174—175/10   | 25 |
| 0.8039/20°                     |               |              |        | 20         | 160/15mm.    | 26 |
|                                | s.            | s            | s.s.   | d. 262     |              | 27 |
|                                |               |              |        |            |              | 28 |

| Name.                                  | Formula.                 | Formula Empirical<br>Weight. Formula. |
|--|--------------------------|---------------------------------------|
| 1 Chlor-acetanilide, <i>o</i>          | $C_6H_4Cl.NH.CO.OH_3$    | 169.57 $C_8H_8ONCl$                   |
| 2 —, <i>m</i>                          | " "                      | 169.57 "                              |
| 3 —, <i>p</i>                          | " "                      | 169.57 "                              |
| 4 —, <i>o</i>                          | $C_6H_5.NH.CO.CH_2Cl$    | 169.57 "                              |
| 5 —acetic acid                         | $CH_3Cl.CO.OH$           | 94.49 $C^2H_3O_2Cl$                   |
| 6 —acetate, ethyl                      | $CH_3Cl.COOC^2H_5$       | 122.54 $C^4H_7O_2Cl$                  |
| 7 —acetone                             | $CH_3.CO.CH_2Cl$         | 92.52 $C^3H_5OCl$                     |
| 8 —acetyl chloride                     | $CH_3Cl.CO.Cl$           | 112.95 $C^2H_2OCl_2$                  |
| 9 —acetylene                           | $C_2HCl$                 | 60.48 $C^2HCl$                        |
| 10 —acrylic acid, $\alpha$             | $CH_2:CCl.CO.OH$         | 106.50 $C^3H_3O_2Cl$                  |
| 11 —, $\beta$                          | $CHCl:CH.CO.OH$          | 106.50 "                              |
| 12 —aniline, <i>o</i>                  | $C_6H_4Cl.NH_2$          | 127.55 $C_6H_6NCl$                    |
| 13 —, <i>m</i>                         | " "                      | 127.55 "                              |
| 14 —, <i>p</i>                         | " "                      | 127.55 "                              |
| 15 —anthraquinone, 1                   | $C_6H_4:(CO)_2:C_6H_3Cl$ | 242.59 $C^{14}H_7O_2Cl$               |
| 16 —, 2                                | " "                      | 242.59 "                              |
| 17 —benzaldehyde, <i>o</i>             | $Cl.C_6H_4.CHO$          | 140.54 $C^7H_5OCl$                    |
| 18 —, <i>m</i>                         | " "                      | 140.54 "                              |
| 19 —, <i>p</i>                         | " "                      | 140.54 "                              |
| 20 —benzene                            | $C_6H_5Cl$               | 112.53 $C^6H_5Cl$                     |
| 21 —benzoic acid, <i>o</i>             | $C_6H_4Cl.CO.OH$         | 156.54 $C^7H_5O_2Cl$                  |
| 22 —, <i>m</i>                         | " "                      | 156.54 "                              |
| 23 —, <i>p</i>                         | " "                      | 156.54 "                              |
| 24 benzyl chloride, <i>p</i>           | $C_6H_4Cl.CH_2Cl$        | 161.00 $C^7H_6Cl_2$                   |
| 25 —, <i>o</i>                         | " "                      | 161.00 "                              |
| 26 —camphor                            | $C^{10}H^{16}Cl_2$       | 207.10 $C^{10}H^{16}Cl_2$             |
| 27 —carbonic ester                     | $COCl(OC^2H_5)$          | 108.52 $C^3H_5OCl$                    |
| 28 —crotonic acid, $\alpha$            | $CH_3.CH:CCl.CO.OH$      | 120.52 $C^4H_5O_2Cl$                  |
| 29 —, $\beta$                          | $CH_3.CCl:CH.CO.OH$      | 120.52 "                              |
| 30 —, $\gamma$                         | $CH_2Cl.CH:CH.CO.OH$     | 120.52 "                              |
| 31 —dinitro benzene,<br>1:3:4 $\alpha$ | $C_6H_3Cl(NO_2)_2$       | 202.53 $C^6H_3O_4N_2Cl$               |
| 32 1:3:4 $\beta$                       | " "                      | 202.53 "                              |
| 33 1:3:4 $\gamma$                      | " "                      | 202.53 "                              |
| 34 1:2:6                               | " "                      | 202.53 "                              |
| 35 1:2:4                               | " "                      | 202.53 "                              |
| 36 1:3:5                               | " "                      | 202.53 "                              |
| 37 —phenol, 4:2:6:1                    | $C_6H_2Cl(NO_2)_2.OH$    | 218.53 $C^6H_3O_5N_2Cl$               |
| 38 —diphenyl, <i>o</i>                 | $C_6H_4Cl.C_6H_5$        | 188.59 $C^{12}H_9Cl$                  |
| 39 —, <i>m</i>                         | " "                      | 188.59 "                              |

| Density<br>$H_2O=1.$ | Solubility in |             |               | M.P.<br>°C.      | B.P.<br>°C.   |    |
|----------------------|---------------|-------------|---------------|------------------|---------------|----|
|                      | Water.        | Alcohol.    | Ether.        |                  |               |    |
| 1.385/22°            |               | s.          | s. $C_6H_6$   | 87—88            |               | 1  |
|                      |               | s.          | s. $C_6H_6$   | 72.5             |               | 2  |
|                      |               | s.          | s.            | 175              |               | 3  |
|                      |               | s.s. acetic | ss.           | 135              |               | 4  |
| 1.3947/73°           | s.            |             |               | 62.5—63.2        | 186           | 5  |
| 1.1585/20°           |               |             |               | liq.             | 143.5         | 6  |
| 0.5158/13°           | s.s.          | m.          | m.            | liq.             | 119           | 7  |
| 1.495                |               |             |               |                  | 106           | 8  |
|                      |               |             |               | gas              |               | 9  |
|                      | m.            | s.          | s.            | 65               | d. 176—181    | 10 |
|                      |               |             | s. $C_6H_6$   | 84—85            |               | 11 |
| 1.2125/20°           | 12:100/15°    |             |               | S.P. - 2.1       | 208.8         | 12 |
| 1.2149/20°           |               |             |               | S.P. - 10.4      | 230           | 13 |
| 1.1704/70°           |               |             |               | 70.5             | 232.3         | 14 |
|                      |               | s.          |               | 162              |               | 15 |
|                      |               | s.          | v.s. $C_6H_6$ | 208              |               | 16 |
|                      |               |             |               | 110              | 208/748mm.    | 17 |
|                      |               |             |               | 17—18            | 213—214       | 18 |
|                      | c.s.s.; h.s.  | s.s.        | s.s.          | 48—49            | 213/748mm.    | 19 |
| 1.1115               |               | s.          |               | - 45             | 132           | 20 |
| 1.544/20°            | 0.21:100/25°  | s.          |               | 139.5            |               | 21 |
|                      | 1:2840/0°     | s.          |               | 156              | subl.         | 22 |
| 1.541/24°            | 1:5288/0°     | s.          | s.            | 234—240          | subl.         | 23 |
|                      |               | h.v.s.      | v.s.          | 29               | 213—214 (222) | 24 |
|                      |               |             |               |                  | 213—214       | 25 |
|                      |               | s.          | v.s.          | 155—155.5        |               | 26 |
| 1.144/15°            |               |             |               | liq.             | 93.1          | 27 |
|                      | 597:100/19°   | v.s.        | v.s.          | 99.5             | 212           | 28 |
|                      |               |             |               | 94—94.5          | 206—211       | 29 |
|                      |               |             |               | 76.5—77.5        | 117—118/13mm. | 30 |
|                      |               | s.          | s.            | 36.3 to $\gamma$ |               | 31 |
|                      |               |             |               |                  |               |    |
|                      |               | s.          |               | 37.1 to $\gamma$ |               | 32 |
|                      |               | s.          | s.            | 38.8             |               | 33 |
| 1.678/16°            |               | v.s.        | s.            | 42               | 315           | 34 |
| 1.697/22°            |               | s.          |               | 50               | 315           | 35 |
|                      |               | s.          | s.            | 53               |               | 36 |
|                      |               |             |               | 80.5             |               | 37 |
|                      |               |             | s. ligroin    | 34               | 267—268       | 38 |
|                      |               |             |               | 89               |               | 39 |

| Name.                                     | Formula.   | Formula Weight. | Empirical Formula.                                  |
|---|--|-----------------|---|
| 1 Chlor diphenyl, <i>p</i>                | " "  | 188.59          | "   |
| 2 — hydrin, $\alpha$                      | $\text{CH}_2\text{Cl}.\text{CHOH}.\text{CH}_2\text{OH}$  | 110.53          | $\text{C}_3\text{H}_7\text{O}_2\text{Cl}$           |
| 3 —, $\beta$                              | $\text{CH}_3.\text{CCl}(\text{OH}).\text{CH}_2\text{OH}$ | 110.53          | "   |
| 4 — malonic acid                          | $\text{CHCl}:(\text{COOH})_2$                            | 138.50          | $\text{C}_3\text{H}_3\text{O}_4\text{Cl}$           |
| 5 — methyl ether                          | $\text{CH}_2\text{Cl}.\text{O}.\text{CH}_3$              | 80.51           | $\text{C}_2\text{H}_5\text{OCl}$                    |
| 6 — — sulphate                            | $\text{CH}_2\text{Cl}.\text{HSO}_4$                      | 146.55          | $\text{CH}_3\text{O}_4\text{SOCl}$                  |
| 7 — naphthalene, $\alpha$                 | $\text{C}_{10}\text{H}_7\text{Cl}$                       | 162.57          | $\text{C}_{10}\text{H}_7\text{Cl}$                  |
| 8 —, $\beta$                              | " "  | 162.57          | "   |
| 9 — nitro benzene, <i>o</i>               | $\text{C}_6\text{H}_4\text{Cl}(\text{NO}_2)$             | 157.53          | $\text{C}_6\text{H}_4\text{O}_2\text{NCl}$          |
| 10 — —, <i>m</i>                          | " "  | 157.53          | "   |
| 11 — —, <i>p</i>                          | $\text{C}_6\text{H}_4\text{Cl}(\text{NO}_2)$             | 157.53          | $\text{C}_6\text{H}_4\text{O}_2\text{NCl}$          |
| 12 — — naphthalene, 4:1                   | $\text{C}_{10}\text{H}_6\text{Cl}(\text{NO}_2)$          | 207.57          | $\text{C}_{10}\text{H}_6\text{O}_2\text{NCl}$       |
| 13 — —, 7:1                               | " "  | 207.57          | "   |
| 14 — — phenol,                            | $\text{C}_6\text{H}_3\text{OH}(\text{NO}_2)\text{Cl}$    | 173.53          | $\text{C}_6\text{H}_4\text{O}_3\text{NCl}$          |
| $\text{OH}:\text{Cl}:\text{NO}_2 = 1:6:2$ |  |                 |   |
| 15 1:5:2                                  | " "  | 173.53          | "   |
| 16 1:4:2                                  | " "  | 173.53          | "   |
| 17 1:2:4                                  | " "  | 173.53          | "   |
| 18 1:4:3                                  | " "  | 173.53          | "   |
| 19 1:5:3                                  | " "  | 173.53          | "   |
| 20 1:6:3                                  | " "  | 173.53          | "   |
| 21 — phenol, <i>o</i>                     | $\text{C}_6\text{H}_4\text{Cl.OH}$                       | 128.53          | $\text{C}_6\text{H}_5\text{OCl}$                    |
| 22 —, <i>m</i>                            | " "  | 128.53          | "   |
| 23 —, <i>p</i>                            | " "  | 128.53          | "   |
| 24 — phthalic acid, 4                     | $\text{C}_6\text{H}_3\text{Cl}(\text{COOH})_2$           | 200.54          | $\text{C}_6\text{H}_3\text{O}_4\text{Cl}$           |
| 25 — propionic acid, $\alpha$             | $\text{CH}_3.\text{CHCl}.\text{COOH}$                    | 108.52          | $\text{C}_3\text{H}_5\text{O}_3\text{Cl}$           |
| 26 — —, $\beta$                           | $\text{CH}_2\text{Cl}.\text{CH}_2.\text{COOH}$           | 108.52          | "   |
| 27 — pyridine, 2                          | $\text{C}_5\text{H}_4\text{N}.\text{Cl}$                 | 113.53          | $\text{C}_5\text{H}_4\text{NCl}$                    |
| 28 —, 3                                   | "  | 113.53          | "   |
| 29 —, 4                                   | "  | 113.53          | "   |
| 30 — quinoline, 2                         | $\text{C}_9\text{H}_6\text{N}.\text{Cl}$                 | 163.56          | $\text{C}_9\text{H}_6\text{NCl}$                    |
| 31 —, 4                                   | "  | 163.56          | "   |
| 32 — toluene, <i>o</i>                    | $\text{C}_6\text{H}_4.(\text{Cl})\text{CH}_3$            | 126.55          | $\text{C}_7\text{H}_7\text{Cl}$                     |
| 33 —, <i>m</i>                            | " "  | 126.55          | "   |
| 34 —, <i>p</i>                            | " "  | 126.55          | "   |
| 35 — trinitro-benzene,                    | $\text{C}_6\text{H}_2\text{Cl}(\text{NO}_2)_3$           | 247.54          | $\text{C}_6\text{H}_2\text{O}_6\text{N}_3\text{Cl}$ |
| 5:1:2:4                                   |  |                 |   |
| 36 2:1:3:5                                | " "  | 247.54          | "   |

| Density<br>$H_2O=1$ . | Solubility in |          |                 | M.P.<br>°C.   | B.P.<br>°C.          |    |
|-----------------------|---------------|----------|-----------------|---------------|----------------------|----|
|                       | Water.        | Alcohol. | Ether.          |               |                      |    |
|                       |               |          | s. ligroin      | 75.5          | 282                  | 1  |
|                       | s.            |          |                 |               | 213                  | 2  |
|                       |               |          |                 |               | 146/18mm.            | 3  |
|                       | s.s.          | s.s.     | s.s.            | 133           | d. slow. 180         | 4  |
|                       | d.            |          |                 | F.Pt. - 103.5 | 59.1—59.3/<br>766mm. | 5  |
|                       |               |          |                 |               |                      | 6  |
| 1.2028/6.4°           |               | s.       | s. $CS_2$       | liq.          | 250—252              | 7  |
| 1.2656/16°            |               | s.       |                 | 56            | 264—266/751mm        | 8  |
| 1.368/22°             | i.            | s.       |                 | 32.5          | 243                  | 9  |
| 1.534                 | i.            | h.s.     | v.s.            | 44.4          | 235.6                | 10 |
| 1.380/22°             | i.            | s.       |                 | 83            | 242                  | 11 |
|                       | i.            | s.       | s.              | 85            |                      | 12 |
|                       | i.            | s.       |                 | 116           |                      | 13 |
|                       | s.s.          |          | s. $CHCl_3$     | 70            |                      | 14 |
|                       |               |          |                 | 38.9          |                      | 15 |
|                       | v.s.s.        | s.       | s., s. $CHCl_3$ | 86—87         |                      | 16 |
|                       | v.s. $CHCl_3$ | v.s.     | v.s.            | 110—111       |                      | 17 |
|                       |               |          |                 | 126—127       |                      | 18 |
|                       |               |          |                 | 147           |                      | 19 |
|                       |               |          |                 | 118—119       |                      | 20 |
|                       |               | s.       |                 | 7             | 175                  | 21 |
|                       |               | s.       | s.              | 32—33         | 214                  | 22 |
| 1.306/20.5°           | s.s.          | v.s.     | v.s.            | 37            | 217                  | 23 |
|                       | s.            | s.       |                 | 148           |                      | 24 |
| 1.28/0°               | m.            | s.       |                 | liq.          | 186                  | 25 |
|                       | v.s.          | v.s.     |                 | 41.5          | 203—205              | 26 |
|                       | s.            |          |                 | liq.          | 166/714mm.           | 27 |
|                       |               |          |                 | nq.           | 148/743.5mm.         | 28 |
|                       | s.            |          |                 | liq.          | 147—148              | 29 |
| 1.2754/16.6°          | i.            | s.       | v.s.            | 37—38         | 275/751mm.           | 30 |
| 1.3766/16.6°          |               | s.       | s.              | 34            | 260—261/744mm        | 31 |
| 1.0807/20°            |               |          |                 | - 34          | 159.4                | 32 |
| 1.07218/20°           |               |          |                 | - 47.8        | 162.2                | 33 |
|                       |               |          |                 | 7.4           | 162.3                | 34 |
|                       |               | s.s.     |                 | 116           |                      | 35 |
| 1.790/22°             | i.            | h.s.     | s.s.            | 83            |                      | 36 |

| Name.                        | Formula.  | Formula Empirical |   |
|------------------------------|---|-------------------|---|
|                              |   | Weight.           | Formula.                                    |
| 1 Chloral                    | $\text{CCl}_3\text{.COH}$   | 147.40            | $\text{C}_2\text{H}_2\text{OCl}_3$          |
| 2 — alcoholate               | $\text{CCl}_3\text{.CH(OC}_2\text{H}_5\text{)OH}$                   | 193.46            | $\text{C}_4\text{H}_7\text{O}_2\text{Cl}_3$ |
| 3 — hydrate                  | $\text{CCl}_3\text{.CH(OH)}_2$                                      | 165.41            | $\text{C}_2\text{H}_3\text{O}_2\text{Cl}_3$ |
| 4 Chloranil                  | $\text{O}_6\text{Cl}_2\text{O}_2$                                   | 245.87            | $\text{C}_6\text{O}_2\text{Cl}_4$           |
| 5 Chloroform                 | $\text{CHCl}_3$   | 119.39            | $\text{CHCl}_3$                             |
| 6 Chloropicrin               | $\text{C(NO}_2\text{)Cl}$   | 164.40            | $\text{CO}_2\text{NCl}$                     |
| 7 Cholesterol                | $\text{C}_{26}\text{H}_{43}\text{OH}$                               | 372.48            | $\text{C}_{26}\text{H}_{44}\text{O}$        |
| 8 — benzoate                 | $\text{C}_{26}\text{H}_{43}\text{O.C}_7\text{H}_5\text{O}$          | 476.55            | $\text{C}_{33}\text{H}_{48}\text{O}_2$      |
| 9 Cholic acid                | $\text{C}_{24}\text{H}_{40}\text{O}_5\text{.H}_2\text{O}$           | 426.46            | $\text{C}_{24}\text{H}_{40}\text{O}_5$      |
| 10 Choline                   | $\text{C}_2\text{H}_4\text{OH.N(CH}_3\text{)}_3\text{OH}$           | 121.16            | $\text{C}_5\text{H}_{15}\text{O}_2\text{N}$ |
| 11 Chrysamminic acid         | $\text{C}_2\text{H}_2(\text{NO})_2(\text{OH})_2\text{O}_2$          | 420.14            | $\text{C}_2\text{H}_2\text{N}_2\text{O}_5$  |
| 12 Chrysaniline              | $\text{C}_{14}\text{H}_{15}\text{N}_3$                              | 285.25            | $\text{C}_{14}\text{H}_{15}\text{N}_3$      |
| 13 Chrysarobin               | $\text{C}_{15}\text{H}_{12}\text{O}_2$                              | 224.17            | $\text{C}_{15}\text{H}_{12}\text{O}_2$      |
| 14 Chrysazine, see           | Dihydroxy anthraquinone   |                   |   |
| 15 Chrysazol, see            | Dihydroxy anthracene  |                   |   |
| 16 Chrysene                  | $\text{C}_{18}\text{H}_{12}$  | 228.19            | $\text{C}_{18}\text{H}_{12}$                |
| 17 Chrysine                  | $\text{C}_{15}\text{H}_{10}\text{O}_4$                              | 254.16            | $\text{C}_{15}\text{H}_{10}\text{O}_4$      |
| 18 Chryso-quinone, 1 : 2     | $\text{C}_{18}\text{H}_{10}\text{O}_2$                              | 258.17            | $\text{C}_{18}\text{H}_{10}\text{O}_2$      |
| 19 — —, 2 : 8                | "   | 258.17            | "   |
| 20 Chrysophanic acid         | $\text{C}_{14}\text{H}_5\text{O}_2(\text{OH})_2\text{CH}_3$         | 254.16            | $\text{C}_{15}\text{H}_{10}\text{O}_4$      |
| 21 Cinchomeronic acid        | see Pyridine dicarboxylic acid                                      |                   |   |
| 22 Cineol                    | $\text{C}_{10}\text{H}_{18}\text{O}$                                | 154.19            | $\text{C}_{10}\text{H}_{18}\text{O}$        |
| 23 Cineolic acid             | $\text{C}_{10}\text{H}_{16}\text{O}_5$                              | 216.18            | $\text{C}_{10}\text{H}_{16}\text{O}_5$      |
| 24 Cinnamic acid             | $\text{C}_6\text{H}_5\text{.CH:CH.COOH}$                            | 148.11            | $\text{C}_9\text{H}_8\text{O}_2$            |
| 25 Cinnamate, benzyl         | $\text{C}_6\text{H}_5\text{.CH:CH.COO.C}_7\text{H}_7$               | 238.19            | $\text{C}_{16}\text{H}_{14}\text{O}_2$      |
| 26 —, ethyl                  | $\text{C}_6\text{H}_5\text{.CH:CH.COO.C}_2\text{H}_5$               | 176.15            | $\text{C}_{11}\text{H}_{12}\text{O}_2$      |
| 27 Cinnamic acid<br>chloride | $\text{C}_6\text{H}_5\text{.CH:CH.COCl}$                            | 166.56            | $\text{C}_9\text{H}_7\text{OCl}$            |
| 28 — aldehyde                | $\text{C}_6\text{H}_5\text{.CH:CH.CHO}$                             | 132.11            | $\text{C}_9\text{H}_8\text{O}$              |
| 29 — alcohol                 | $\text{C}_6\text{H}_5\text{.CH:CH.CH}_2\text{OH}$                   | 134.13            | $\text{C}_9\text{H}_{10}\text{O}$           |
| 30 — anhydride               | $(\text{C}_9\text{H}_7\text{O})_2\text{:O}$                         | 278.20            | $\text{C}_{18}\text{H}_{14}\text{O}_3$      |
| 31 — carboxylic acid, o      | $\text{COOH.C}_6\text{H}_4\text{.CH:CH.COOH}$                       | 192.11            | $\text{C}_{18}\text{H}_{10}\text{O}_4$      |
| 32 Citraconic acid           | $\text{C}_3\text{H}_4(\text{COOH})_2$                               | 130.07            | $\text{C}_5\text{H}_6\text{O}_4$            |
| 33 — anhydride               | $\text{C}_3\text{H}_4\text{: (CO)}_2\text{:O}$                      | 112.06            | $\text{C}_5\text{H}_4\text{O}_3$            |
| 34 Citral                    | $\text{C}_{10}\text{H}_{16}\text{O}$                                | 152.18            | $\text{C}_{10}\text{H}_{16}\text{O}$        |
| 35 Citramalic acid           | $\text{COOH(CH}_3\text{):C(OH).CH}_2\text{.COOH}$                   | 148.09            | $\text{C}_5\text{H}_8\text{O}_5$            |
| 36 Citrene                   | $\text{C}_{10}\text{H}_{16}$  | 136.18            | $\text{C}_{10}\text{H}_{16}$                |
| 37 Citric acid               | $\text{C}_3\text{H}_4(\text{OH})(\text{COOH})_3\text{.H}_2\text{O}$ | 210.11            | $\text{C}_8\text{H}_8\text{O}_7$            |

| Density<br>$H_2O=1$ . | Solubility in |                 |               | M.P.<br>°C.  | B.P.<br>°C. |    |
|-----------------------|---------------|-----------------|---------------|--------------|-------------|----|
|                       | Water.        | Alcohol.        | Ether.        |              |             |    |
| 1.512/20°             | v.s.          | s.              |               | -57.5        | 97.7        | 1  |
| 1.143/40°             | s. d.         | s.              |               | 46           | 115         | 2  |
| 1.5745/66°            | s.            | s.              | s. $CS_2$     | 47.4         | 96—98 d.    | 3  |
|                       | i.            | h.s.s.          | s.s.          | 290          | subl        | 4  |
| 1.5039/11.8°          | v.s.s.        | s.              | s.            | -63.2        | 61.2        | 5  |
| 1.0697/20°            | i.            | 3.7 : 1         |               | -64          | 111.9       | 6  |
| 1.067                 | i.            | h. 1 : 9        | s., s. $CS_2$ | 145—146      |             | 7  |
|                       |               | i.              | s.            | 146.6        |             | 8  |
|                       | v.s.s.        | s.              | s.s.          | 197          |             | 9  |
|                       | s.            | v.s.            | v.s.          |              |             | 10 |
|                       | i.            | s.              | s.            |              |             | 11 |
|                       | s.s.          | s.s.            |               | 267—270      |             | 12 |
|                       | i.            | s.              | s. $CHCl_3$   | 170—178      |             | 13 |
|                       |               |                 |               |              |             | 14 |
|                       |               |                 |               |              |             | 15 |
|                       | s.s.          | 0.097 : 100/16° | s. acetic     | 250          | 448         | 16 |
|                       | s. alk.       | c. 1 : 180      | s.s.          | 275          | subl.       | 17 |
|                       | s. $H_2SO_4$  | h.s.            | s.s.          | 237          | subl.       | 18 |
|                       |               |                 |               | 288—290 d.   |             | 19 |
|                       | i.            | h. 1 : 24       | s.            | 196          | subl.       | 20 |
|                       |               |                 |               |              |             | 21 |
| 0.9267/20°            | d.            |                 |               | -1           | 176         | 22 |
|                       | c. 1 : 70     |                 | s.            | 196—197 d.   |             | 23 |
| 1.249                 | 0.054b :      | s.              | v.s.          | 133          | 300         | 24 |
|                       | 100/25°       |                 |               |              |             |    |
|                       |               |                 |               | 39           | 225—235     | 25 |
| 1.0498/20°            |               | s.              |               | 12           | 271         | 26 |
|                       |               |                 |               | 35—36        | 170—171/58  | 27 |
| 1.0497/24°            |               | s.              | s.            | -7.5         | 126—127/15  | 28 |
| 1.044/20°             | s.s.          | v.s.            | v.s.          | 33           | 250         | 29 |
|                       | i.            | s.s.            |               | 136          |             | 30 |
|                       | s.s.          | s.              | s.s.          | 173—175      |             | 31 |
| 1.617                 | 1 : 0.42/15°  |                 |               | 86           | 91 d.       | 32 |
| 1.2504/15°            |               |                 |               | 7            | 213         | 33 |
| 0.8972/15°            | i.            |                 |               |              | 224—225 d.  | 34 |
|                       | s.            | s.              | s.            | 119          | d. 130      | 35 |
| 0.85/15°              |               | s.              |               | liq.         | 168—168.5   | 36 |
| 1.542                 | c. 133 : 100  | 87 : 100        | 9.1 : 100     | 153, an. 100 | d.          | 37 |

| Name.                                      | Formula.  | Formula Empirical |                   |
|--|---|-------------------|-------------------|
|  |   | Weight.           | Formula.          |
| 1 Citronellal                              | $C_{10}H_{18}O$   | 154.19            | $C_{10}H_{18}O$   |
| 2 Citronellol                              | $C_{10}H_{20}O$   | 156.21            | $C_{10}H_{20}O$   |
| 3 Cœrulein                                 | $C_{20}H_{12}O_6$   | 348.20            | $C_{20}H_{12}O_6$ |
| 4 Cœrulignone                              | $C_{16}H_{16}O_6$   | 340.21            | $C_{16}H_{16}O_6$ |
| 5 Collidine, $\alpha$                      | $C_5H_2N(CH_3)_3$   | 121.14            | $C_8H_{11}N$      |
| 6 —, $\beta$                               | " "   | 121.14            | "                 |
| 7 —, $\gamma$                              | " "   | 121.14            | "                 |
| 8 Coniferin                                | $C_{16}H_{22}O_8 \cdot 2H_2O$   | 378.29            | $C_{16}H_{22}O_8$ |
| 9 Coniferyl alcohol                        | $C_{10}H_{12}O_3$   | 180.15            | $C_{10}H_{12}O_3$ |
| 10 Conylene                                | $C_8H_{14}$   | 110.15            | $C_8H_{14}$       |
| 11 Coumalic acid                           | $C_5H_3O_2(COOH)$   | 140.06            | $C_6H_4O_4$       |
| 12 Coumalin                                | $CH \begin{matrix} \diagup CH:CH \\ \diagdown CH.CO \end{matrix} \rangle O$ | 96.06             | $C_5H_4O_2$       |
| 13 Coumaric acid, $o$                      | $C_6H_4(OH)C_2H_2.COOH$   | 164.11            | $C_9H_8O_3$       |
| 14 —, $p$                                  | " "   | 164.11            | "                 |
| 15 Coumarin                                | $C_8H_4 \begin{matrix} \diagup CH:CH \\ \diagdown O-CO \end{matrix}$        | 146.10            | $C_9H_6O_2$       |
| 16 Creatine                                | $NH_2.C(:NH).N(CH_3).CH_2$<br>$COOH.(H_2O)$                                 | 131.12            | $C_4H_9O_2N_3$    |
| 17 — <i>iso.</i> , methyl<br>glycocoyamide | $C_4H_9N_3O_2$  | 131.12            | "                 |
| 18 Creatinine, methyl<br>glycocoyamidine   | $NH:C \begin{matrix} \diagup NH-CO \\ \diagdown N(CH_3).CH_2 \end{matrix}$  | 113.11            | $C_4H_7ON_3$      |
| 19 Cresol, $o$                             | $CH_3.C_6H_4.OH$  | 108.10            | $C_7H_8O$         |
| 20 —, $m$                                  | " "   | 108.10            | "                 |
| 21 —, $p$                                  | " "   | 108.10            | "                 |
| 22 Cresorcinol, see                        | Dihydroxy toluene   |                   |                   |
| 23 Cresotinic acid, see                    | Hydroxy toluic acid   |                   |                   |
| 24 Croconic acid                           | $C_5O_3(OH)_2(3H_2O)$   | 142.04            | $C_5H_2O_5$       |
| 25 Crotonaldehyde, $\alpha$                | $CH_3.CH:CH.CHO$  | 70.07             | $C_4H_6O$         |
| 26 Crotonic acid, $\alpha$                 | $CH_3.CH:CH.COOH$   | 86.07             | $C_4H_6O_2$       |
| 27 —, $\beta$                              | $CH_2:CH.CH_2.COOH$   | 86.07             | "                 |
| 28 Crotonyl alcohol                        | $CH_2:CH:CH.CH_2OH$   | 72.08             | $C_4H_8O$         |
| 29 Crotonylene                             | $CH_3.C:C.CH_3$   | 54.07             | $C_4H_6$          |
| 30 Cubebine                                | $C_{20}H_{20}O_6$   | 356.26            | $C_{20}H_{20}O_6$ |



| Density<br>H <sub>2</sub> O=1. | Solubility in |            |                                   | M.P.<br>°C. | B.P.<br>°C.    |    |
|--------------------------------|---------------|------------|-----------------------------------|-------------|----------------|----|
|                                | Water.        | Alcohol.   | Ether.                            |             |                |    |
| 0.8538/17.5°                   |               |            |                                   |             | 205—208        | 1  |
| 0.8565/17.5°                   |               |            |                                   |             | 221—222        | 2  |
|                                | v.s.s.        | s.s.       | s. alk.                           |             |                | 3  |
|                                | h.s.          | i.         | s. H <sub>2</sub> SO <sub>4</sub> | d.          |                | 4  |
| 0.929/0°                       | s.s.          | s.         | s.                                | liq.        | 160            | 5  |
| 0.966/0°                       | i.            | s.         |                                   | liq.        | 195—196        | 6  |
| 0.917/15°                      | i.            | s.         | s.                                | liq.        | 171—172        | 7  |
|                                | h.s.          | s.         | i.                                | 185         | d.             | 8  |
|                                | h.s.s.        | s.         | s.                                | 73—74       |                | 9  |
| 0.76/15°                       |               | s.         |                                   |             | 125            | 10 |
|                                | c.s.s.        | s.         | s.s.                              | 205—210 d.  | subl.          | 11 |
| 1.2                            | m.            | s.         | s.                                | 5           | 206—209 d.     | 12 |
|                                | h.s.          | s.         | v.s.s.                            | 214         | d.             | 13 |
|                                | c.v.s.s.      | v.s.       | v.s.                              | 215         |                | 14 |
| 0.9348/7.3°                    | s.s.          | v.s.       | s.                                | 67          | 290—290.5 subl | 15 |
|                                | h.s.          | i.         |                                   | 220 d       |                | 16 |
|                                | 1:12          | h.s.s.     |                                   | d. 220      |                | 17 |
|                                | s.            | h.s.       |                                   |             |                | 18 |
| 1.0427/23.2°                   | s.s.          | s.         | s.                                | 30          | 190.8          | 19 |
| 1.0350/13.6°                   | s.s.          | s.         | s.                                | 3—4         | 200.5          | 20 |
| 1.0340/17.7°                   | s.s.          | s.         | s.                                | 36          | 201.1          | 21 |
|                                |               |            |                                   |             |                | 22 |
|                                | v.s.          | s.         |                                   | an. 100     |                | 23 |
| 0.8557/17.3°                   | s.            |            |                                   | liq.        | 163—164        | 24 |
| 1.018                          | 1:12/15°      |            | s. ligroin.                       | 71—72       | 180—181        | 25 |
| 1.018                          | m.            |            |                                   |             | 172            | 26 |
|                                |               |            |                                   |             | 117—120        | 27 |
|                                | i.            | s. cupram. |                                   | liq.        | 27.2—27.6      | 28 |
|                                | v.s.s.        | 1.31:      | 3.75/100                          | 131—132     |                | 29 |
|                                |               |            |                                   |             |                | 30 |

| Name.                                 | Formula.  | Formula Empirical<br>Weight. Formula.             |
|---------------------------------------|---|---|
| 1 Cumarone                            | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{O} \diagdown \\ \diagdown \text{CH} \diagup \end{array} \text{CH}$                       | 118.09 $\text{C}_8\text{H}_6\text{O}$             |
| 2 Cumene                              | $\text{C}_6\text{H}_5.\text{CH}:(\text{CH}_3)_2$  | 120.14 $\text{C}_9\text{H}_{12}$                  |
| 3 Cumidic acid                        | $(\text{CH}_3)_2:\text{C}_6\text{H}_2:(\text{COOH})_2$  | 194.13 $\text{C}_{10}\text{H}_{10}\text{O}_4$     |
| 4 Cumidine, 1:2:4:5                   | $(\text{CH}_3)_3\text{C}_6\text{H}_2.\text{NH}_2$   | 135.16 $\text{C}_9\text{H}_{13}\text{N}$          |
| 5 —, amino <i>iso</i> -propyl benzene | $\text{C}_3\text{H}_7.\text{C}_6\text{H}_4.\text{NH}_2$   | 135.16 „  |
| 6 Cumin alcohol, <i>p</i>             | $\text{C}_3\text{H}_7.\text{C}_6\text{H}_4.\text{CH}_2\text{OH}$  | 150.16 $\text{C}_{10}\text{H}_{14}\text{O}$       |
| 7 — aldehyde, cuminol                 | $\text{C}_3\text{H}_7.\text{C}_6\text{H}_4.\text{CHO}$  | 148.15 $\text{C}_{10}\text{H}_{12}\text{O}$       |
| 8 Cuminic acid                        | $\text{C}_3\text{H}_7.\text{C}_6\text{H}_4.\text{COOH}$   | 164.15 $\text{C}_{10}\text{H}_{12}\text{O}_2$     |
| 9 Cumylic acid, 1:2:4:5               | $(\text{CH}_3)_3\text{C}_6\text{H}_2.\text{COOH}$   | 164.15 $\text{C}_{10}\text{H}_{12}\text{O}_2$     |
| 10 Curcumin                           | $\text{C}_{14}\text{H}_{14}\text{O}_4$  | 246.18 $\text{C}_{14}\text{H}_{14}\text{O}_4$     |
| 11 Cyamelide                          | $(\text{CNOH})_x$   | (43.03)   |
| 12 Cyan-acetic acid                   | $\text{CH}_2\text{CN}.\text{COOH}$  | 85.05 $\text{C}_3\text{H}_3\text{O}_2\text{N}$    |
| 13 — amide                            | $\text{NC}.\text{NH}_2$   | 42.04 $\text{CH}_3\text{N}_2$                     |
| 14 — anilide                          | $\text{C}_6\text{H}_5.\text{NH}.\text{CN}$  | 118.10 $\text{C}_7\text{H}_6\text{N}_2$           |
| 15 — aniline                          | $(\text{C}_6\text{H}_5\text{N})(\text{CN})_2$   | 238.20 $\text{C}_{14}\text{H}_{14}\text{N}_4$     |
| 16 — carbonic ester                   | $\text{CN}.\text{COOO} \text{H}_5$  | 99.07 $\text{C}_4\text{H}_5\text{O}_2\text{N}$    |
| 17 — naphthalene, $\alpha$            | $\text{C}_{10}\text{H}_7\text{CN}$  | 153.12 $\text{C}_{11}\text{H}_7\text{N}$          |
| 18 —, $\beta$                         | „   | 153.12 „  |
| 19 — propionic acid, $\alpha$         | $\text{CH}_3.\text{CH}(\text{CN})\text{COOH}$   | 99.07 $\text{C}_4\text{H}_5\text{O}_2\text{N}$    |
| 20 — sulphide                         | $(\text{CN})_2:\text{S}$  | 84.09 $\text{C}_2\text{N}_2\text{S}$              |
| 21 — uramide                          | $\text{C}_3\text{N}_3(\text{NH}_2)_2$   | 110.10 $\text{C}_3\text{H}_2\text{N}_5$           |
| 22 Cyanethine                         | $\text{CH}_3.\text{C}=\text{CH}=\text{C}.\text{NH}_2$<br>$\begin{array}{c}    \quad   \\ \text{N}.\text{C}(\text{CH}_3)=\text{N} \end{array}$ | 123.13 $\text{C}_6\text{H}_9\text{N}_3$           |
| 23 Cyanogen                           | $\text{C}_2\text{N}_2$  | 52.03 $\text{C}_2\text{N}_2$                      |
| 24 — chloride, liq.                   | $\text{CN}.\text{Cl}$   | 61.48 $\text{CNCl}$                               |
| 25 —, solid                           | $\text{C}_3\text{N}_3\text{Cl}_3$   | 184.43 $\text{C}_3\text{N}_3\text{Cl}_3$          |
| 26 Cyanuric acid, <i>iso</i> .        | $\text{C}_3\text{N}_3(\text{OH})_3.2\text{H}_2\text{O}$   | 165.10 $\text{C}_3\text{H}_3\text{O}_3\text{N}_3$ |
| 27 Cyclo heptane                      | $\text{C}_7\text{H}_{14}$   | 98.15 $\text{C}_7\text{H}_{14}$                   |
| 28 — heptanone, suberone              | $\text{CO} \begin{array}{c} \diagup \text{CH}_2\text{CH}_2\text{CH}_2 \\ \diagdown \text{CH}_2\text{CH}_2\text{CH}_2 \end{array}$             | 112.13 $\text{C}_7\text{H}_{12}\text{O}$          |
| 29 — hexane                           | $\text{C}_6\text{H}_6(\text{H}_6)$  | 84.13 $\text{C}_6\text{H}_{12}$                   |
| 30 — dione, 1:3                       | $\text{C}_6\text{H}_4\text{O}_2(\text{H}_4)$  | 112.09 $\text{C}_6\text{H}_8\text{O}_2$           |
| 31 —, 1:4                             | „ „   | 112.09 „  |
| 32 — hexanol                          | $\text{C}_6\text{H}_5(\text{H}_6)\text{OH}$   | 100.13 $\text{C}_6\text{H}_{12}\text{O}$          |

| Density<br>H <sub>2</sub> O=1. | Solubility in |             |                                      | M.P.<br>°C. | B.P.<br>°C.            |    |
|--------------------------------|---------------|-------------|--------------------------------------|-------------|------------------------|----|
|                                | Water.        | Alcohol.    | Ether.                               |             |                        |    |
|                                |               | 100/12°     |                                      |             |                        |    |
| 1.0767/15°                     | i.            |             |                                      | liq.        | 171—172                | 1  |
| 0.866/15°                      | i.            | s.          | s.                                   | -75.1       | 152.5—153.5            | 2  |
|                                | s.s.          | h.s.        | v.s.                                 | >320        |                        | 3  |
| 0.9526                         | s.            | s.          |                                      | 64          | 225                    | 4  |
|                                | s.            | s.          | s. C <sub>6</sub> H <sub>6</sub>     |             | 213.5—214.5/<br>732mm. | 5  |
| 0.9775/15°                     | s.s.          | m.          | m.                                   | liq.        | 246.6                  | 6  |
| 0.9832                         | h.s.          | s.          | s.                                   | liq.        | 237                    | 7  |
| 1.1625/4°                      | 0.015 :       | s.          | s.                                   | 117         | subl.                  | 8  |
|                                | 100/25°       |             |                                      |             |                        |    |
|                                | h.s.s.        | v.s.        | s., s. C <sub>6</sub> H <sub>6</sub> | 149—150     |                        | 9  |
|                                | s. alk.       | s.          | s.                                   | 178         |                        | 10 |
|                                | i.            |             |                                      |             | d.                     | 11 |
|                                | i.            | v.s.        | v.s.                                 | 69          | d.                     | 12 |
|                                | v.s.          | v.s.        | v.s.                                 | 41—42       | 143—144/18             | 13 |
|                                | s.s.          | s.          | s.                                   | 47          |                        | 14 |
|                                | i.            | s.s.        | s.s.                                 | 214         | d.                     | 15 |
| >H <sub>2</sub> O              | i.            | s.          | s.                                   | liq.        | 115—116                | 16 |
|                                |               | s.          |                                      | 33.5        | 296.5                  | 17 |
|                                |               | s.          |                                      | 66.5        | 304—305                | 18 |
|                                | v.s.          | v.s.        |                                      | d. 140      |                        | 19 |
|                                | s.            | s.          | s.                                   | 60          | d.                     | 20 |
|                                | s.s.          | i.          | i.                                   | subl. d.    |                        | 21 |
|                                | s.            |             |                                      | 180—181     | subl.                  | 22 |
|                                | 4.5 : 1 vol.  | 22 : 1 vol. |                                      | -35         | -21                    | 23 |
| >H <sub>2</sub> O              | s.s.          | s.          | s.                                   |             | 15.5                   | 24 |
| 1.32                           |               |             | s.                                   | 145         | 190                    | 25 |
|                                | 1 : 40        | s.          |                                      |             |                        | 26 |
| 0.8904/20°                     |               |             |                                      | -13 to -12  | 117—117.5/<br>743mm.   | 27 |
|                                |               |             |                                      |             | 179—181                | 28 |
| 0.7237/20°                     |               |             |                                      | 6.5         | 80.7                   | 29 |
|                                | d.            | s.s.        | s.s.                                 | 105—106     |                        | 30 |
|                                | v.s.s.        | s.s.        | s.s.                                 | 78          |                        | 31 |
|                                | 1 : 28 c.     |             |                                      | 25          | 161.1                  | 32 |

| Name.                                | Formula.  | Formula Weight. | Empirical Formula    |
|--------------------------------------|---|-----------------|----------------------|
| 1 Cyclo hexene                       | $C_6H_8(H_4)$   | 82.11           | $C_6H_{10}$          |
| 2 — pentane                          | $CH_2 \begin{cases} CH_2CH_2 \\   \\ CH_2CH_2 \end{cases}$                              | 70.10           | $C_5H_{10}$          |
| 3 — pentanone,<br>adipinketone       | $CO \begin{cases} CH_2CH_2 \\   \\ CH_2CH_2 \end{cases}$                                | 84.09           | $C_5H_8O$            |
| 4 Cymene, <i>p</i>                   | $CH_3.C_6H_4.C_3H_7$  | 134.16          | $C_{10}H_{14}$       |
| 5 —, <i>o</i>                        | " "   | 134.16          | "                    |
| 6 —, <i>m</i>                        | " "   | 134.16          | "                    |
| 7 Dambose                            | $C_6H_{12}O_6.2H_2O$  | 216.16          | $C_6H_{12}O_6$       |
| 8 Daphnetin                          | $C_9H_6O_4$   | 178.09          | $C_9H_6O_4$          |
| 9 Deca hydro-<br>naphthalene         | $C_{10}H_8(H_{10})$   | 138.19          | $C_{10}H_{18}$       |
| 10 — — quinoline                     | $C_9H_7N(H_{10})$   | 139.19          | $C_9H_{17}N$         |
| 11 Decane, <i>norm.</i>              | $C_{10}H_{22}$  | 142.23          | $C_{10}H_{22}$       |
| 12 Decyl alcohol, <i>norm.</i>       | $C_{10}H_{21}OH$  | 158.23          | $C_{10}H_{22}O$      |
| 13 Dehydracetic acid                 | $CH_3.CO.CH.CO.CH$<br>$\quad \quad \quad \parallel$<br>$\quad \quad \quad CO.O.CO.CH_3$ | 168.10          | $C_8H_8O_4$          |
| 14 Desoxalic acid                    | $C_2H(OH).(COOH)_3$   | 194.07          | $C_5H_6O_8$          |
| 15 Desoxybenzoin                     | $C_6H_5.CO.CH_2.C_6H_5$   | 196.17          | $C_{14}H_{12}O$      |
| 16 Dextrin                           | $C_6H_{10}O_5$  | 162.11          | $C_6H_{10}O_5$       |
| 17 Dextrose                          | $C_6H_{12}O_6$  | 180.13          | $C_6H_{12}O_6$       |
| 18 Diacetamide                       | $(CH_3CO)_2:NH$   | 101.09          | $C_4H_7O_2N$         |
| 19 Diacetanilide                     | $(CH_3CO)_2:N.C_6H_5$   | 177.15          | $C_{10}H_{11}O_2N$   |
| 20 Diacethydroquinone                | $C_6H_4O_2(CH_3CO)_2$   | 194.13          | $C_{10}H_{10}O_4$    |
| 21 Diacetin                          | $C_6H_5OH(O.COCH_3)_2$  | 176.13          | $C_7H_{12}O_5$       |
| 22 Diacetyl                          | $CH_3.CO.CO.CH_3$   | 86.09           | $C_4H_6O_2$          |
| 23 — acetic ester                    | $(CH_3CO).CH.COOC_2H_5$   | 129.10          | $C_6H_8O_3$          |
| 24 — catechol                        | $(CH_3.CO.O)_2:C_6H_4$  | 194.13          | $C_{10}H_{10}O_4$    |
| 25 — hydroquinone                    | " "   | 194.13          | "                    |
| 26 — glucose                         | $C_5H_6(OCH_3.CO)_2(OH)_3$<br>$\quad \quad \quad COH$                                   | 264.18          | $C_{10}H_{16}O_8$    |
| 27 — <i>m</i> -phenylene<br>diamine  | $C_6H_4:(NH.CO.CH_3)_2$   | 192.16          | $C_{10}H_{12}O_2N_2$ |
| 28 — resorcin                        | $(CH_3.CO.O)_2:C_6H_4$  | 194.13          | $C_{10}H_{10}O_4$    |
| 29 — succinic acid,<br>diethyl ester | $C_2H_2(COCH_3)_2(COOC_2H_5)_2$   | 258.20          | $C_{12}H_{18}O_6$    |

| Density<br>$H_2O=1.$ | Solubility in |             |             | M.P.<br>°C. | B.P.<br>°C. |    |
|----------------------|---------------|-------------|-------------|-------------|-------------|----|
|                      | Water.        | Alcohol.    | Ether.      |             |             |    |
| 0.8102/20°           |               |             |             |             | 83—84       | 1  |
| 0.751/20°            |               |             |             |             | 49—50       | 2  |
|                      |               |             |             |             | 130—130.5   | 3  |
| 0.852/15°            | i.            | s.          | s.          | -73.5       | 175         | 4  |
| 0.858                | i.            | s.          |             |             | 157         | 5  |
| 0.865                | i.            | s.          |             |             | 175—176     | 6  |
| 1.524                | v.s.          | i. (abs.)   |             | 225         | 319         | 7  |
|                      | h.v.s.        | h.s.        | v.s.s.      | d. 253—256  |             | 8  |
| 0.837/19°            |               |             |             |             | 187—188     | 9  |
|                      | h.s.          | v.s.        | s.          | 48.2—48.5   | 204/714mm.  | 10 |
| 0.7342/15°           |               |             |             | -30 to -32  | 173         | 11 |
| 0.8389/7°            |               | s.          | v.s.        | 7           | 231         | 12 |
|                      | s.            | h.s.        |             | 108.5—109   | 269.9       | 13 |
|                      | v.s.          | v.s.        |             | liq.        | d.          | 14 |
|                      | s.s.          | s.          | s.          | 60—61       | 320—322     | 15 |
| 1.03845              | s.            | i. (abs.)   |             |             |             | 16 |
| 1.54—1.57            | 81:100        | s.          | s. $CH_3OH$ | an. 146     | d.          | 17 |
|                      | v.s.          | s.          | s.          | 77.5—78     | 222.5—223.5 | 18 |
|                      |               | s. $C_6H_6$ | s. ligroin. | 38          | 145—146/13  | 19 |
|                      | h.s.s.        | s.s.        | v.s.        | 123—124     |             | 20 |
|                      | m.            |             | m.          | 40          | 259         | 21 |
| 0.9734/22°           | 1:4/15°       |             |             |             | 87.5—88     | 22 |
| 1.064/15°            | s.s.          |             |             | liq.        | d. 200—205  | 23 |
|                      |               |             |             | 62—64       |             | 24 |
|                      | h.s.          | s.s.        | s.          | 121         |             | 25 |
|                      | s.            | s.          | s.          | <100        |             | 26 |
|                      | c.s.s.; h.s.  | s.          |             | 191         |             | 27 |
|                      |               | s.          |             | 88—89       | 278         | 28 |
|                      |               |             |             |             |             | 29 |

| Name   | Formula.   | Formula Empirical<br>Weight. Formula.                     |
|--|--|---|
| 1 Diacetyl <i>m</i> -toluylene<br>diamine, 1:2:4                       | $\text{CH}_3 \cdot \text{C}_6\text{H}_3 : (\text{NH} \cdot \text{CO} \cdot \text{CH}_3)_2$                             | 206.18 $\text{C}_{11}\text{H}_{14}\text{O}_2\text{N}_2$   |
| 2 Diacetylene  | $\text{CH} : \text{C} \cdot \text{C} : \text{CH}$  | 50.04 $\text{C}_2\text{H}_2$                              |
| 3 Diallyl  | $(\text{C}_2\text{H}_5)_2$   | 82.11 $\text{C}_4\text{H}_8$                              |
| 4 Dialuric acid  | $\text{C}_4\text{H}_5\text{N}_2\text{O}$   | 144.07 $\text{C}_4\text{H}_5\text{O}_2\text{N}_2$         |
| 5 Diamino-<br>anthraquinone, 1:4                                       | $\text{C}_{14}\text{H}_6\text{O}_2(\text{NH}_2)_2$   | 238.17 $\text{C}_{14}\text{H}_{10}\text{O}_2\text{N}_2$   |
| 6 —, 1:5   | ,, ,,  | 238.17 ,,   |
| 7 —, 1:8   | ,, ,,  | 238.17 ,,   |
| 8 — benzoic acid,<br>$\text{COOH} : \text{NH}_2 : \text{NH}_2 = 1:2:3$ | $\text{C}_6\text{H}_5(\text{NH}_2)_2\text{COOH}$   | 152.12 $\text{C}_7\text{H}_8\text{O}_2\text{N}_2$         |
| 9 1:3:4  | ,, ,,  | 152.12 ,,   |
| 10 1:3:5   | ,, ,,, $\text{H}_2\text{O}$  | 170.14 ,,   |
| 11 — benzophenone, 2:2'  | $(\text{C}_6\text{H}_4\text{NH})_2\text{CO}$   | 210.17 $\text{C}_{13}\text{H}_{10}\text{ON}_2$            |
| 12 —, 4:4'   | ,, ,,  | 210.17 ,,   |
| 13 — diphenylamine, 4:4'   | $(\text{C}_6\text{H}_4 \cdot \text{NH}_2)_2\text{NH}$  | 199.19 $\text{C}_{12}\text{H}_{13}\text{N}_3$             |
| 14 — diphenylmethane   | $(\text{C}_6\text{H}_4 \cdot \text{NH}_2)_2\text{CH}_2$ , 4:4'   | 198.20 $\text{C}_{13}\text{H}_{14}\text{N}_2$             |
| 15 — stilbene  | $(\text{C}_6\text{H}_4 \cdot \text{NH}_2)_2\text{C}_2\text{H}_2$   | 210.20 $\text{C}_{14}\text{H}_{14}\text{N}_2$             |
| 16 — triphenylmethane  | $\text{C}_6\text{H}_5 \cdot \text{CH}(\text{C}_6\text{H}_4 \cdot \text{NH}_2)_2$ , 4:4'                                | 274.26 $\text{C}_{19}\text{H}_{18}\text{N}_2$             |
| 17 Dianisidine   | $\text{C}_{12}\text{H}_5(\text{OCH}_3)_2(\text{NH}_2)_2$   | 244.22 $\text{C}_{14}\text{H}_{16}\text{O}_2\text{N}_2$   |
| 18 Diazo-acetic ester  | $(\text{COOC}_2\text{H}_5)\text{CHN}_2$  | 114.09 $\text{C}_4\text{H}_6\text{O}_2\text{N}_2$         |
| 19 — amino-benzene   | $\text{C}_6\text{H}_5 \cdot \text{N}_2 \cdot \text{NH} \cdot \text{C}_6\text{H}_5$                                     | 197.18 $\text{C}_{12}\text{H}_{11}\text{N}_3$             |
| 20 — — naphthalene   | $\text{C}_{10}\text{H}_7 \cdot \text{N}_2 \cdot \text{NH} \cdot \text{C}_{10}\text{H}_7$                               | 297.25 $\text{C}_{20}\text{H}_{15}\text{N}_3$             |
| 21 — benzene chloride  | $\text{C}_6\text{H}_5 \cdot \text{N}_2 \cdot \text{Cl}$  | 140.55 $\text{C}_6\text{H}_5\text{N}_2\text{Cl}$          |
| 22 — — cyanide   | $\text{C}_6\text{H}_5 \cdot \text{N}_2 \cdot \text{CN} \cdot \text{HCN}$   | 158.13 $\text{C}_8\text{H}_6\text{N}_4$                   |
| 23 — — imide   | $\text{C}_6\text{H}_5 \cdot \text{N} \begin{array}{c} \diagup \text{N} \\ \parallel \\ \diagdown \text{N} \end{array}$ | 119.10 $\text{C}_6\text{H}_5\text{N}_3$                   |
| 24 — — nitrate   | $\text{C}_6\text{H}_5 \cdot \text{N}_2 \cdot \text{NO}_3$  | 167.10 $\text{C}_6\text{H}_5\text{O}_3\text{N}_3$         |
| 25 — — sulphonie acid, <i>m</i>  | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{N}_2 \\   \\ \text{SO}_3 \end{array}$                             | 184.14 $\text{C}_6\text{H}_4\text{O}_3\text{N}_2\text{S}$ |
| 26 — — — —, <i>p</i>   | ,, ,,  | 184.14 ,,   |
| 27 — methane   | $\text{CH}_2\text{N}_2$  | 42.04 $\text{CH}_2\text{N}_2$                             |
| 28 Dibenzoyl catechol  | $\text{C}_6\text{H}_4 : (\text{O} \cdot \text{CO} \cdot \text{C}_6\text{H}_5)_2$                                       | 318.21 $\text{C}_{20}\text{H}_{14}\text{O}_4$             |
| 29 — hydroquinone  | ,, ,,  | 318.21 ,,   |
| 30 — <i>m</i> -phenylene<br>diamine                                    | $\text{C}_6\text{H}_4 : (\text{NH} \cdot \text{CO} \cdot \text{C}_6\text{H}_5)_2$                                      | 316.24 $\text{C}_{20}\text{H}_{16}\text{O}_2\text{N}_2$   |
| 31 — resorcinol  | $\text{C}_6\text{H}_4 : (\text{O} \cdot \text{CO} \cdot \text{C}_6\text{H}_5)_2$                                       | 318.21 $\text{C}_{20}\text{H}_{14}\text{O}_4$             |

| Density<br>$H_2O=1$ . | Solubility in         |          |                   | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------|-----------------------|----------|-------------------|-------------|-------------|----|
|                       | Water.                | Alcohol. | Ether.            |             |             |    |
| 0.6895/20°            | i.                    |          |                   | 224         |             | 1  |
|                       | s.s.                  |          |                   | gas         |             | 2  |
|                       | v.s.s.                | s.       | s., s. $C_6H_6$   | liq.        | 59—59.6/744 | 3  |
|                       |                       |          |                   | 268         | subl.       | 4  |
|                       | s.s.                  | s.       | s.                | 319         |             | 5  |
|                       | i.                    | s.       |                   | 262         |             | 6  |
|                       | s.s.                  |          |                   | 190—191 d   |             | 7  |
|                       |                       |          |                   |             |             | 8  |
|                       | h.s.                  |          |                   | d. 210—211  |             | 9  |
|                       | h.s.                  | v.s.     | v.s.              | an. 236     | d           | 10 |
|                       | h.s.                  | s.       | s.                | 172         |             | 11 |
|                       | h.s.                  | s.       | s.                | 239         | d. 250      | 12 |
|                       | s.s.                  |          | s.                | 158         | d.          | 13 |
|                       | v.s.                  | v.s.     | s. $C_6H_6$       | 88—89       |             | 14 |
| 1.083/24°             | s.s.                  | s.       |                   | 227—228     | subl. d.    | 15 |
|                       | v.s.s.                | s.       | s.                | 139         |             | 16 |
|                       | h.s.s.                | h.s.     | s.s., s. $C_6H_6$ | 135         |             | 17 |
|                       | s.s.                  | m.       | m.                |             | 140—141 d.  | 18 |
|                       | i.                    | h.s.     | v.s.              | 96          | expl.       | 19 |
|                       |                       |          | s.                | expl. 174   |             | 20 |
|                       | s.                    | s.s.     |                   |             |             | 21 |
|                       | s.s.                  |          |                   | 70          |             | 22 |
|                       | i.                    |          |                   |             |             |    |
| 1.124/0°              |                       | s.s.     | s.s.              | oil         | 73.5/22—24  | 23 |
| 1.37                  | v.s.                  | s.s.     | v.s.s.            | expl.       |             | 24 |
|                       | s., d. 60°            |          |                   | d.          |             | 25 |
|                       | c.i., 60° s.,<br>h.d. |          |                   |             |             | 26 |
|                       | i.                    | s.s.     | s.                |             | gas         | 27 |
|                       |                       | h.v.s.   | s.s.              | 84          |             | 28 |
|                       |                       | v.s.     |                   | 199         |             | 29 |
|                       |                       |          |                   | 240         |             | 30 |
|                       |                       | v.s.     |                   | 117         |             | 31 |

| Name.                                    | Formula.                           | Formula Weight. | Empirical Formula.   |
|--|------------------------------------|-----------------|----------------------|
| 1 Dibenzoyl succinic acid, diethyl ester | $C_2H_2(CO.C_6H_5)_2(COOC_2H_5)_2$ | 382.29          | $C_{22}H_{22}O_6$    |
| 2 — <i>m</i> -toluylene diamine 1:2:4    | $CH_3.C_6H_3:(NH.CO.C_6H_5)_2$     | 330.26          | $C_{21}H_{18}O_2N_2$ |
| 3 Dibenzyl                               | $C_6H_5.CH_2.CH_2.C_6H_5$          | 182.18          | $C_{14}H_{14}$       |
| 4 — amine                                | $(C_6H_5.CH_2)_2:NH$               | 197.20          | $C_{14}H_{15}N$      |
| 5 — ether, see                           | Benzyl ether                       |                 |                      |
| 6 — ketone                               | $(C_6H_5.CH_2)_2:CO$               | 210.19          | $C_{15}H_{14}O$      |
| 7 Dibenzylidene acetone                  | $(C_6H_5.CH:CH)_2CO$               | 234.20          | $C_{17}H_{14}O$      |
| 8 Dibromo anthracene                     | $C_6H_4:CBr_2:C_6H_4, 9:10$        | 335.97          | $C_{14}H_8Br_2$      |
| 9 — anthraquinone, 1:2                   | $C_6H_4:(CO)_2:C_6H_4Br_2$         | 366.90          | $C_{14}H_6O_2Br_2$   |
| 10 —, 2:6                                | $C_6H_3Br:(CO)_2:C_6H_3Br$         | 366.90          | "                    |
| 11 —, 2:7                                | " "                                | 366.90          | "                    |
| 12 — benzene, <i>o</i>                   | $C_6H_4Br_2$                       | 235.90          | $C_6H_4Br_2$         |
| 13 —, <i>m</i>                           | "                                  | 235.90          | "                    |
| 14 —, <i>p</i>                           | "                                  | 235.90          | "                    |
| 15 — ethane, <i>asym.</i>                | $CH_3.CHBr_2$                      | 187.88          | $C_2H_4Br_2$         |
| 16 — succinic acid                       | $C_2H_2Br_2(COOH)_2$               | 275.89          | $C_4H_4O_2Br_2$      |
| 17 Dichloro acetal                       | $CHCl_2.CH:(OC_2H_5)_2$            | 187.05          | $C_6H_{12}O_4Cl_2$   |
| 18 — acetaldehyde                        | $CHCl_2.CHO$                       | 112.95          | $C_2H_2OCl_2$        |
| 19 — acetamide                           | $CHCl_2.CONH_2$                    | 127.96          | $C_2H_3ONCl_2$       |
| 20 — acetic acid                         | $CHCl_2.COOH$                      | 128.95          | $C_2H_3O_2Cl_2$      |
| 21 — acetate, ethyl                      | $CHCl_2.COOC_2H_5$                 | 156.99          | $C_4H_7O_2Cl_2$      |
| 22 — acetone                             | $CHCl_2.CO.CH_3$                   | 126.97          | $C_3H_4OCl_2$        |
| 23 — acetyl-chloride                     | $CHCl_2.COCl$                      | 147.40          | $C_2H_2OCl_2$        |
| 24 — aniline, 1:2:4                      | $C_6H_3Cl_2.NH_2$                  | 162.00          | $C_6H_5NCl_2$        |
| 25 —, 1:2:5                              | "                                  | 162.00          | "                    |
| 26 —, 1:3:5                              | "                                  | 162.00          | "                    |
| 27 —, 1:3:4                              | "                                  | 162.00          | "                    |
| 28 — anthracene, 9:10                    | $C_{14}H_8Cl_2$                    | 247.05          | $C_{14}H_8Cl_2$      |
| 29 — anthraquinone, 1:2                  | $C_{14}H_6O_2:Cl_2$                | 277.04          | $C_{14}H_6O_2Cl_2$   |
| 30 —, 1:4                                | " "                                | 277.04          | "                    |
| 31 —, 1:5                                | " "                                | 277.04          | "                    |
| 32 —, 1:8                                | " "                                | 277.04          | "                    |
| 33 —, 2:6                                | " "                                | 277.04          | "                    |
| 34 —, 2:7                                | " "                                | 277.04          | "                    |
| 35 — benzene, <i>o</i>                   | $C_6H_4Cl_2$                       | 146.98          | $C_6H_4Cl_2$         |
| 36 —, <i>m</i>                           | "                                  | 146.98          | "                    |
| 37 —, <i>p</i>                           | "                                  | 146.98          | "                    |



| Density<br>$H_2O=1$ . | Solubility in |          |             | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------|---------------|----------|-------------|-------------|-------------|----|
|                       | Water.        | Alcohol. | Ether.      |             |             |    |
| 1.244/20°             |               | 1 : 200  | v.s.s.      |             |             | 1  |
|                       |               |          | v.s.        | 224         |             | 2  |
| 0.9416/80.6°          | s. $CS_2$     | s.s.     | s.          | 52          | 284         | 3  |
| 1.033/14°             | s. $CS_2$     | s.       | s.          | liq.        | 300         | 4  |
|                       |               |          |             |             |             | 5  |
|                       |               |          | s.s.        | 33          | 331         | 6  |
|                       | s. acetone    | s.s.     | s.s.        | 112—113     |             | 7  |
|                       | s.h. $C_6H_6$ | v.s.s.   | s.s.        | 220—221     | subl.       | 8  |
|                       |               | s.s.     | s. $C_6H_6$ | 265         |             | 9  |
|                       |               | v.s.s.   | s. $C_6H_6$ | 289—290     |             | 10 |
|                       |               |          |             | 323         |             | 11 |
| 1.977/18°             |               | s.       | s. $C_6H_6$ | 5.6         | 223.8/751   | 12 |
| 1.955/19°             |               | s.       |             | 1—2         | 219.4/758.4 | 13 |
| 2.261 cryst.          |               | s.       | s.          | 87.2        | 219         | 14 |
| 2.100/17.5°           |               |          |             |             | 112.5       | 15 |
|                       | h.s.          | s.       | s.          | 255—256     |             | 16 |
| 1.1383/14°            | s.s.          |          |             | liq.        | 183—184     | 17 |
|                       | i.            |          |             | liq.        | 88—90       | 18 |
|                       |               |          |             | 97—98       | 233—234/745 | 19 |
| 1.5216/15°            |               |          |             | —4          | 189—191     | 20 |
| 1.282/20°             |               |          |             | liq.        | 156—157     | 21 |
| 1.236/21°             | s.s.          |          |             | liq.        | 120         | 22 |
|                       |               |          |             |             | 108—111     | 23 |
|                       |               | s.       |             | 63          | 245         | 24 |
|                       |               | s.       |             | 50          | 251         | 25 |
|                       |               | s.       |             | 50.5        | 259—260     | 26 |
|                       |               | s.       |             | 71          | 272         | 27 |
|                       | s. $C_6H_6$   | s.s.     | s.s.        | 209         |             | 28 |
|                       |               |          |             | 261         |             | 29 |
|                       |               |          |             | 187.5—188   |             | 30 |
|                       | s.            |          |             | 248—251     |             | 31 |
|                       | s.            |          |             | 199         |             | 32 |
|                       |               |          |             | 280—282     |             | 33 |
|                       |               |          |             | 208—210     |             | 34 |
| 1.3278/0°             |               | s.       | s.s.        | —14         | 179         | 35 |
| 1.3047/0°             |               | s.       |             | —18         | 172         | 36 |
| 1.526/21.5°           | s. $C_6H_6$   | h.m.     | v.s.        | 53          | 172         | 37 |

| Name.                                   | Formula.                 | Formula Weight. | Empirical Formula. |
|---|--------------------------|-----------------|--------------------|
| 1 Dichlor benzoic acid,<br>1:3:4        | $C_6H_3Cl_2.COOH$        | 190.99          | $C_7H_4O_2Cl_2$    |
| 2 ———, 1:2:5                            | " "                      | 190.99          | "                  |
| 3 —diphenyl, <i>p</i>                   | $C_6H_4Cl.C_6H_4Cl$      | 234.04          | $C_{12}H_8Cl_2$    |
| 4 —ethane, <i>asym.</i>                 | $CH_3.CHCl_2$            | 98.96           | $C_2H_3Cl_2$       |
| 5 —ether                                | $CH_3Cl.CHCl_2.O.O_2H_5$ | 143.00          | $C_2H_4OCl_2$      |
| 6 —ethylene, <i>asym.</i>               | $CH_2:CCl_2$             | 96.95           | $C_2H_2Cl_2$       |
| 7 —, <i>sym.</i>                        | $CHCl:CHCl$              | 96.95           | "                  |
| 8 —hydrin, $\alpha \gamma$              | $CH_2Cl.CHOH.CH_2Cl$     | 128.98          | $C_3H_6OCl_2$      |
| 9 —, $\beta \gamma$                     | $CH_2Cl.CHCl.CH_2OH$     | 128.98          | "                  |
| 10 —, $\alpha \alpha$                   | $CH_2.CHOH.CHCl_2$       | 128.98          | "                  |
| 11 —naphthalene, 1:2                    | $C_{10}H_6Cl_2$          | 197.02          | $C_{10}H_6Cl_2$    |
| 12 —, 1:3                               | "                        | 197.02          | "                  |
| 13 —, 1:4                               | "                        | 197.02          | "                  |
| 14 —, 1:5                               | "                        | 197.02          | "                  |
| 15 —, 1:6                               | "                        | 197.02          | "                  |
| 16 —, 1:7                               | "                        | 197.02          | "                  |
| 17 —, 1:8                               | "                        | 197.02          | "                  |
| 18 —, 2:3                               | $C_{10}H_6Cl_2$          | 197.02          | $C_{10}H_6Cl_2$    |
| 19 —, 2:6                               | "                        | 197.02          | "                  |
| 20 —, 2:7                               | "                        | 197.02          | "                  |
| 21 —nitro benzene,<br>$NO_2:Cl_2=1:2:3$ | $Cl_2:C_6H_3.NO_2$       | 191.98          | $C_6H_3O_2NCl_2$   |
| 22 ———, 1:2:4                           | " "                      | 191.98          | "                  |
| 23 ———, 1:2:5                           | " "                      | 191.98          | "                  |
| 24 ———, 1:3:4                           | " "                      | 191.98          | "                  |
| 25 ———, 1:3:5                           | " "                      | 191.98          | "                  |
| 26 — <i>m</i> phenylene<br>diamine, 2:5 | $C_6H_2Cl_2(NH_2)_2$     | 177.02          | $C_6H_6N_2Cl_2$    |
| 27 —phthalic acid, 3:6                  | $Cl_2:C_6H_2:(COOH)_2$   | 234.99          | $C_8H_4O_4Cl_2$    |
| 28 —anhydride, 3:6                      | $Cl_2:C_6H_2:(CO)_2:O$   | 216.98          | $C_8H_2O_3Cl_2$    |
| 29 —quinoline, 2:3                      | $C_9H_5NCl_2$            | 198.02          | $C_9H_5NCl_2$      |
| 30 —, 2:4                               | "                        | 198.02          | "                  |
| 31 —, 2:6                               | "                        | 198.02          | "                  |
| 32 —, 2:7                               | "                        | 198.02          | "                  |
| 33 —, 5:6                               | "                        | 198.02          | "                  |
| 34 —, 5:7                               | "                        | 198.02          | "                  |
| 35 —, 5:8                               | "                        | 198.02          | "                  |
| 36 —, 6:8                               | "                        | 198.02          | "                  |

| Density<br>H <sub>2</sub> O=1. | Solubility in                      |          |                                  | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|------------------------------------|----------|----------------------------------|-------------|-------------|----|
|                                | Water.                             | Alcohol. | Ether.                           |             |             |    |
|                                | s.s.                               | s.       |                                  | 201—202     |             | 1  |
|                                | 1 : 1193/11°                       | s.       |                                  | 156         | 301         | 2  |
| 1.1743/20°                     |                                    |          |                                  | 148         | 315         | 3  |
| 1.174/23°                      |                                    |          |                                  | -96.7       | 57.5/751mm. | 4  |
| 1.250/15°                      |                                    |          |                                  |             | 140—145     | 5  |
|                                |                                    |          |                                  |             | 37          | 6  |
|                                |                                    |          |                                  |             | 55          | 7  |
| 1.396/16°                      | 1 : 6/72°                          |          |                                  | liq.        | 174—175     | 8  |
| 1.3799/0°                      |                                    |          |                                  | liq.        | 183         | 9  |
|                                |                                    |          |                                  |             | 146—148     | 10 |
|                                |                                    | s.       |                                  | 34—35       | 280—282     | 11 |
|                                |                                    |          |                                  | 61          | 289         | 12 |
|                                |                                    | s.       |                                  | 67—68       | 286—287/740 | 13 |
|                                |                                    | s.       |                                  | 107         | subl.       | 14 |
|                                |                                    |          |                                  | 48          |             | 15 |
|                                |                                    | v.s.     |                                  | 62          | 286         | 16 |
|                                |                                    |          |                                  | 83          |             | 17 |
|                                |                                    | c.v.s.   | s.                               | 120         |             | 18 |
|                                |                                    | v.s.     | s.                               | 135         | 285         | 19 |
|                                |                                    | h.s.     |                                  | 114—115     |             | 20 |
|                                |                                    |          |                                  | 61—62       | 257—258     | 21 |
|                                |                                    |          |                                  | 93          | 258.5       | 22 |
| 1.669/22°                      |                                    | c.s.s.   | s. C <sub>6</sub> H <sub>6</sub> | 55          | 266         | 23 |
|                                |                                    |          |                                  | 43          | 255—256     | 24 |
|                                |                                    |          |                                  | 65.4        |             | 25 |
|                                |                                    |          |                                  | 99—100      |             | 26 |
|                                | h.s.s.                             | s.s.     | s.s.                             | 163 d.      |             | 27 |
|                                |                                    |          |                                  | 187         | 339         | 28 |
|                                | v.s. C <sub>6</sub> H <sub>6</sub> | v.s.     | v.s.                             | 104—105     |             | 29 |
|                                |                                    |          |                                  | 67          | 280—282     | 30 |
|                                |                                    |          |                                  | 156         |             | 31 |
|                                |                                    |          |                                  | 98—99       |             | 32 |
|                                |                                    |          |                                  | 85          |             | 33 |
|                                |                                    |          |                                  | 116—117     |             | 34 |
|                                |                                    | s.       | s.                               | 92—93       |             | 35 |
|                                |                                    | s.       |                                  | 103—104     |             | 36 |

| Name.                                  | Formula.                                 | Formula Weight. | Empirical Formula. |
|--|--|-----------------|--------------------|
| 1 Dichlor quinone, 2:6                 | $C_6H_2O_2Cl_2$                          | 176.97          | $C_6H_2O_2Cl_2$    |
| 2 —, 2:3                               | "  | 176.97          | "                  |
| 3 —, 2:5                               | "  | 176.97          | "                  |
| 4 — stilbene                           | $C_{14}H_{10}O$                          | 249.07          | $C_{14}H_{10}O$    |
| 5 Dicyan diamide                       | $HN:C(NH_2).NH.CN$                       | 84.08           | $C_2H_4N_4$        |
| 6 — diamidine                          | $HN:C(NH_2).NH.CO.NH_2$                  | 102.10          | $C_2H_6ON_4$       |
| 7 Diethyl acetic acid                  | $(C_2H_5)_2:CH.CO.OH$                    | 116.13          | $C_6H_{12}O_2$     |
| 8 — acetoacetic acid,<br>ethyl ester   | $CH_3CO.C:(C_2H_5)_2(COOC_2H_5)$         | 186.19          | $C_{10}H_{18}O_3$  |
| 9 — amine                              | $(C_2H_5)_2:NH$                          | 73.12           | $C_4H_{11}N$       |
| 10 — amino phenol, <i>p</i> .          | $(C_2H_5)_2N.C_6H_4OH$                   | 165.18          | $C_{10}H_{15}ON$   |
| 11 — aniline                           | $C_6H_5.N:(C_2H_5)_2$                    | 149.18          | $C_{10}H_{15}N$    |
| 12 — benzene, <i>p</i>                 | $C_6H_4:(C_2H_5)_2$                      | 134.16          | $C_{10}H_{14}$     |
| 13 — cyanamide                         | $CN.N:(C_2H_5)_2$                        | 98.12           | $C_5H_{10}N_2$     |
| 14 — glycollic acid                    | $(C_2H_5)_2:C(OH).COOH$                  | 132.13          | $C_6H_{12}O_3$     |
| 15 — ketone                            | $(C_2H_5)_2:CO$                          | 86.11           | $C_5H_{10}O$       |
| 16 — malonic acid                      | $(C_2H_5)_2C:(COOH)_2$                   | 160.13          | $C_7H_{12}O_4$     |
| 17 — oxamic acid, ethyl<br>ester       | $CON(C_2H_5)_2.COOC_2H_5$                | 173.17          | $C_8H_{15}O_3N$    |
| 18 — phosphine                         | $(C_2H_5)_2:PH$                          | 90.15           | $C_4H_{11}P$       |
| 19 — phosphoric acid                   | $PO(OC_2H_5)_2.OH$                       | 154.15          | $C_4H_{11}O_4P$    |
| 20 — sulphate, see                     | Ethyl sulphate                           |                 |                    |
| 21 — urea, $\alpha$                    | $CO:(NH.C_2H_5)_2$                       | 116.14          | $C_5H_{12}ON_2$    |
| 22 —, $\beta$                          | $NH_2.CO.N:(C_2H_5)_2$                   | 116.14          | "                  |
| 23 Diethylene diamine,<br>(piperazine) | $NH:(C_2H_4)_2:NH$                       | 86.12           | $C_4H_{10}N_2$     |
| 24 — glycol                            | $CH_2OH.CH_2.O.CH_2$<br>$CH_2OH$         | 106.10          | $C_4H_{10}O_3$     |
| 25 Digallic acid, $\alpha$             | $(OH)_3C_6H_2.COOC_6H_2(OH)_2$<br>$COOH$ | 322.15          | $C_{14}H_{10}O_9$  |
| 26 Diglycerol                          | $C_6H_{14}O_5$                           | 166.14          | $C_6H_{14}O_5$     |
| 27 Diglycollamide acid                 | $NH:(CH_2.CO.OH)_2$                      | 133.09          | $C_4H_7O_4N$       |
| 28 Diglycollic acid                    | $O:(CH_2.CO.OH)_2$                       | 134.07          | $C_4H_6O_5$        |
| 29 Dihydro acrylic acid                | $C_6H_6O_3$                              | 126.08          | $C_6H_6O_3$        |
| 30 — benzene, 1:2                      | $C_6H_8H_2$                              | 80.09           | $C_6H_8$           |
| 31 — carveol, $\alpha$                 | $C_{10}H_{18}O$                          | 154.19          | $C_{10}H_{18}O$    |
| 32 — carvone                           | $C_{10}H_{16}O$                          | 152.18          | $C_{10}H_{16}O$    |
| 33 — cymene                            | $C_{10}H_{14}H_2$                        | 136.18          | $C_{10}H_{16}$     |
| 34 — naphthalene, 1:4                  | $C_{10}H_8H_2$                           | 130.13          | $C_{10}H_{10}$     |

| Density<br>$H_2O=1$ | Solubility in |          |             | M.P.<br>°C. | B.P.<br>°C. |    |
|---------------------|---------------|----------|-------------|-------------|-------------|----|
|                     | Water.        | Alcohol. | Ether.      |             |             |    |
|                     | h.s.s.        | h.v.s.   | s. $CHCl_3$ | 120         |             | 1  |
|                     |               |          |             | 96          |             | 2  |
|                     |               |          |             | 161         |             | 3  |
|                     |               | s.       | s.          | 170         |             | 4  |
|                     | s.            | s.       | s.          | 204         | d.          | 5  |
|                     | s.            | s.       | s. ac.      | 105         |             | 6  |
| 0.9355/0°           |               |          |             |             | 151—152     | 7  |
| 0.9743/15°          |               |          |             |             | 218         | 8  |
| 0.7116/15°          | v.s.          | s.       |             | -40         | 55.5/759mm. | 9  |
|                     |               |          |             | 74          | 276—280     | 10 |
| 0.939/18°           | i.            | s.       | s.          | -38.8       | 215.5       | 11 |
| 0.8622/18°          | i.            | s.       | s.          | liq.        | 182—183     | 12 |
|                     |               |          |             | liq.        | 186         | 13 |
|                     | 1: 2.8        |          |             | 80          | subl. 50    | 14 |
| 0.8175/16.6°        | 1: 24         |          |             |             | 102.7       | 15 |
|                     | 65:100/16°    | s.s.     | s.s.        | 121         |             | 16 |
|                     |               |          |             |             | 260         | 17 |
| $>H_2O$             |               |          |             |             | 85          | 18 |
|                     | v.s.          | c.v.s.   |             |             |             | 19 |
|                     |               |          |             |             |             | 20 |
| 1.0415              | s.            | s.       | s.          | 112—113     | 263         | 21 |
|                     |               | v.s.     | v.s.        | 74          |             | 22 |
|                     | v.s.          | v.s.     |             | 104         | 145—146     | 23 |
| 1.132/0°            | s.            | s.       | s.          |             | 250         | 24 |
|                     | s.            | s.       | i.          |             | 282 d.      | 25 |
|                     | h.v.s.        |          | i.          |             | 220—230/10  | 26 |
|                     | 1: 41/5°      | i.       | i.          | 247.5       |             | 27 |
|                     | s.            | s.       | s.          | 148         | d.          | 28 |
|                     | s.            | s.       |             |             | 97/35mm.    | 29 |
|                     |               |          |             |             | 80.5        | 30 |
| 0.927/20°           |               |          |             | liq.        | 221         | 31 |
| 0.928/19°           |               |          |             | liq.        | 221/758mm.  | 32 |
|                     |               |          |             |             | 174         | 33 |
|                     |               |          |             | 15.5        | 212         | 34 |

| Name.  | Formula.   | Formula Weight.            | Empirical Formula                          |
|--|--|----------------------------|--|
| 1 Dihydro phthalic acid, 1:4:2:3                   | $(\text{H}_2):\text{C}_6\text{H}_4:(\text{COOH})_2$  | 136.10                     | $\text{C}_8\text{H}_8\text{O}_4$           |
| 3 ———, <i>tere.</i>                                | „ „  | 136.10                     | „  |
| 4 —quinoline                                       | $\text{C}_9\text{H}_9\text{N}$   | 131.13                     | $\text{C}_9\text{H}_9\text{N}$             |
| 5 —resorcinol                                      | $\text{C}_6\text{H}_6\text{O}_2.\text{H}_2$  | 112.09                     | $\text{C}_6\text{H}_8\text{O}_2$           |
| 6 Dihydroxy acetone                                | $(\text{CH}_2\text{OH})_2:\text{CO}$   | 90.06                      | $\text{C}_3\text{H}_6\text{O}_3$           |
| 7 —anthracene, 1:8, chrysazol                      | $\text{C}_{14}\text{H}_8(\text{OH})_2$   | 210.15                     | $\text{C}_{14}\text{H}_{10}\text{O}_2$     |
| 8 ———, 1:5, rufol                                  | „ „  | 210.15                     | „  |
| 9 —anthroquinones:                                 | $\text{C}_{14}\text{H}_6\text{O}_2:(\text{OH})_2$  | 240.13                     | $\text{C}_{14}\text{H}_8\text{O}_4$        |
| 10 1:2, Alizarin                                   | „ „  | 240.13                     | „  |
| 11 1:3, Purpuroxanthene, Xanthopurpurin            | „ „  | 240.13                     | „  |
| 12 1:4, Quinizarin                                 | „ „  | 240.13                     | „  |
| 13 1:5, Anthrarufin                                | „ „  | 240.13                     | „  |
| 14 1:6,  | „ „  | 240.13                     | „  |
| 15 1:7,  | „ „  | 240.13                     | „  |
| 16 1:8, Chrysazin                                  | „ „  | 240.13                     | „  |
| 17 2:3, Hystazarin                                 | „ „  | 240.13                     | „  |
| 18 2:6, Anthraflavic acid                          | „ „  | 240.13                     | „  |
| 19 2:7, <i>iso</i> -Anthraflavic acid              | „ „  | 240.13                     | „  |
| 20 —benzene, <i>o</i> , pyrocatechol               | $\text{C}_6\text{H}_4(\text{OH})_2$  | 110.08                     | $\text{C}_6\text{H}_6\text{O}_2$           |
| 21 ———, <i>m</i> , resorcinol                      | „  | 110.08                     | „  |
| 22 ———, <i>p</i> , hydroquinone                    | „  | 110.08                     | „  |
| 23 —benzoic acid, hydroxy salicylic protocatechoic | $(\text{OH})_2:\text{C}_6\text{H}_3.\text{COOH}$<br>2:5:1<br>3:4:1<br>3:4:1                              | 154.08<br>154.08<br>154.08 | $\text{C}_7\text{H}_6\text{O}_4$<br>„<br>„ |
| 24 —benzophenone, 2:4'                             | $(\text{C}_6\text{H}_4\text{OH})_2:\text{CO}$  | 214.15                     | $\text{C}_{13}\text{H}_{10}\text{O}_3$     |
| 25 ———, 4:4'                                       | „ „  | 214.15                     | „  |
| 26 ———, 3:3'                                       | „ „  | 214.15                     | „  |
| 27 ———, benzoyl pyro-catechol                      | $\text{C}_6\text{H}_5.\text{CO}.\text{C}_6\text{H}_3(\text{OH})_2.\frac{1}{2}\text{H}_2\text{O}$         | 236.16                     | „  |
| 28 ———, benz. resorcinol                           | „ „  | 214.15                     | „  |
| 29 —cinnamic acid, 1:3:4                           | $(\text{OH})_2:\text{C}_6\text{H}_3.\text{C}_2\text{H}_2.\text{COOH}$<br>$\frac{1}{2}\text{H}_2\text{O}$ | 189.12                     | $\text{C}_9\text{H}_8\text{O}_4$           |
| 30 —diphenylmethane                                | $(\text{C}_6\text{H}_4\text{OH})_2:\text{CH}_2, 4:4'$  | 200.16                     | $\text{C}_{13}\text{H}_{12}\text{O}_2$     |

| Density<br>H <sub>2</sub> O=1. | Water.         | Solubility in |                         | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|----------------|---------------|-------------------------|-------------|-------------|----|
|                                |                | Alcohol.      | Ether.                  |             |             |    |
|                                | 1:100 c.       | s.            | s.s.                    | 153         |             | 1  |
|                                | i.             |               |                         |             |             | 2  |
|                                |                |               |                         |             |             | 3  |
|                                |                |               |                         | 220—226     |             | 4  |
|                                | v.s.           | v.s.          | v.s.s.                  | 104—106     |             | 5  |
|                                | v.s.           | h.s.          | v.s.s.                  | 68—75       |             | 6  |
|                                |                | s.            | s. alk.                 | d. 225      |             | 7  |
|                                |                | s.            | s. alk.                 | d. 265      |             | 8  |
|                                |                |               |                         |             |             | 9  |
|                                | 0.034:100/100° | s.s.          | s.s.; s.CS <sub>2</sub> | 289—290     | 420         | 10 |
|                                |                | s.s.          |                         | 262—263     |             | 11 |
|                                |                | s.s.          | s.                      | 194—195     |             | 12 |
|                                | i.             | v.s.          | s.                      | 280         |             | 13 |
|                                |                |               |                         | 269         |             | 14 |
|                                |                | s.s.          | s.                      | 291—293     |             | 15 |
|                                |                | s.            | s.                      | 190—192     |             | 16 |
|                                |                | h.s.          | h.s.                    | >280        |             | 17 |
|                                | i.             |               | i.                      | >330        |             | 18 |
|                                |                | s.            | i.                      | >330        |             | 19 |
|                                |                |               |                         |             |             | 20 |
| 1.375/15°                      | s.             | s.            | s.                      | 105.5       | 245         |    |
| 1.283                          | 86.4:100/0°    | s.            | s.                      | 111.6       | 276.5       | 21 |
| 1.326/15°                      | 5.85:100/15°   | s.            | s.                      | 170.3       | 285         | 22 |
|                                |                |               |                         |             |             | 23 |
|                                | h.s.           | s.            | s.                      | 196         | d.          |    |
| 1.542/4°                       | 1:54/14°       | v.s.          | s.                      | 200         | d.          |    |
|                                | h.s.           | s.            | s.                      | 232—233     |             |    |
|                                | h.s.s.         | h.s.          | s.                      | 144         |             | 24 |
|                                | h.s.           | s.            | s.                      | 210         |             | 25 |
|                                | s.             | s.            |                         | 162—163     |             | 26 |
|                                | h.s.           | s.            | s. alk.                 | an. 145     |             | 27 |
|                                | h.s.           | s.            | s.                      | 144         |             | 28 |
|                                | v.s.           | v.s.          | v.s.                    | d. 124      |             | 29 |
|                                |                | s.            | s.                      | 158         | subl.       | 30 |

| Name.  | Formula.   | Formula Empirical<br>Weight. Formula |
|--|--|--------------------------------------|
| 1 Dihydroxy<br>naphthalene, 1:4              | $C_{10}H_6(OH)_2$                                  | 160.11 $C_{10}H_8O_2$                |
| 2 —, 1:2                                     | „  | 160.11 „                             |
| 3 —, 1:5                                     | „  | 160.11 „                             |
| 4 —, 1:8                                     | „  | 160.11 „                             |
| 5 —, 2:3                                     | „  | 160.11 „                             |
| 6 —, 2:6                                     | „  | 160.11 „                             |
| 7 —, 2:7                                     | „  | 160.11 „                             |
| 8 —quinone, 2:5                              | $C_6H_2O_2(OH)_2$                                  | 140.06 $C_6H_4O_4$                   |
| 9 —stearic acid, $\alpha \beta$              | $C_{18}H_{34}O_2(OH)_2$                            | 316.28 $C_{18}H_{36}O_4$             |
| 10 —tartaric acid                            | $[C(OH)_2COOH]_2$                                  | 182.07 $C_4H_6O_8$                   |
| 11 —terephthalic acid,<br>2:5                | $C_6H_2(OH)_2(COOH)_2 \cdot 2H_2O$                 | 234.12 $C_8H_6O_6$                   |
| 12 —toluene, homopyro-<br>catechol, 1:3:4    | $CH_3 \cdot C_6H_3 : (OH)_2$                       | 124.10 $C_7H_8O_2$                   |
| orcinol, 1:3:5                               | „ „ $H_2O$   | 142.08 „                             |
| iso-orcinol, $\beta$                         | „ „  | 124.10 „                             |
| cresorcinol, 1:2:4                           | „ „  | 124.10 „                             |
| hydrotoluquinone,<br>1:2:5                   | „ „  | 124.10 „                             |
| 13 —xylene, 4:6:1:3                          | $C_6H_2(CH_3)_2(OH)_2$                             | 138.12 $C_8H_{10}O_2$                |
| 14 —, 2:5:1:4                                | „ „  | 138.12 „                             |
| 15 —, 2:6:1:4                                | „ „  | 138.12 „                             |
| 16 Di-iodo benzene, <i>o</i>                 | $C_6H_4I_2$  | 329.90 $C_6H_4I_2$                   |
| 17 —, <i>m</i>                               | „  | 329.90 „                             |
| 18 —, <i>p</i>                               | „  | 329.90 „                             |
| 19 Di-iso butylamine                         | $(C_4H_9)_2 : NH$                                  | 129.20 $C_8H_{19}N$                  |
| 20 — butylene                                | $(CH_3)_2 : C : CH \cdot C(CH_3)_3$                | 112.17 $C_8H_{16}$                   |
| 21 — butyl ketone                            | $C_4H_9 \cdot CO \cdot C_4H_9$                     | 142.19 $C_9H_{18}O$                  |
| 22 — propyl ketone                           | $C_3H_7 \cdot CO \cdot C_3H_7$                     | 114.15 $C_7H_{14}O$                  |
| 23 Dimethyl acetoacetic<br>acid, ethyl ester | $CH_3CO \cdot C(CH_3)_2COOC_2H_5$                  | 158.15 $C_8H_{14}O_3$                |
| 24 —, methyl ester                           | $CH_3CO \cdot C(CH_3)_2COOCH_3$                    | 144.13 $C_7H_{12}O_3$                |
| 25 —amine                                    | $(CH_3)_2 : NH$                                    | 45.08 $C_2H_7N$                      |
| 26 —amino azo benzene                        | $(CH_3)_2 : N \cdot C_6H_4 \cdot N_2 \cdot C_6H_4$ | 215.13 $C_{14}H_{15}N_3$             |
| 27 —aniline                                  | $C_6H_5 \cdot N : (CH_3)_2$                        | 121.14 $C_8H_{11}N$                  |
| 28 —anthracene, 1:6                          | $C_{14}H_8 : (CH_3)_2$                             | 206.19 $C_{16}H_{14}$                |
| 29 —, 1:8                                    | „ „  | 206.19 „                             |
| 30 —, 2:6                                    | „ „  | 206.19 „                             |
| 31 —, 2:7                                    | „ „  | 206.19 „                             |



| Density<br>$H_2O=1$ . | Solubility in |                   |                   | M.P.<br>°C. | B.P.<br>°C.              |    |
|-----------------------|---------------|-------------------|-------------------|-------------|--------------------------|----|
|                       | Water.        | Alcohol.          | Ether.            |             |                          |    |
|                       | h.s.          | h.s.              | s.                | 173         |                          | 1  |
|                       | s.            |                   | s. alk.           | 60          |                          | 2  |
|                       | h.s.          | s                 | s.                | 250         |                          | 3  |
|                       | h.s.s.        | s. $C_6H_6$       | s.                | 140         |                          | 4  |
|                       | h.s.s.        | s.                | s.                | 159         |                          | 5  |
|                       | c.s.s.        | s.                | s.                | 215—216     | subl.                    | 6  |
|                       | h.s.          | s.s.              | s. $C_6H_6$       | 190         | subl.                    | 7  |
|                       | c.s.s.        | v.s.              | s.s.              |             | sub. 215—220 & d.        | 8  |
|                       | v.s.          | 0.6 : 100<br>/19° | 0.2 : 100<br>/18° | 126         |                          | 9  |
|                       | h.s.          | s.s.              | s.s.              | 98 d        |                          | 10 |
|                       |               |                   |                   | d.          |                          | 11 |
|                       | v.s.          | v.s.              | v.s.              | 65          | 251                      | 12 |
| 1.29                  | s.            | s.                | s.                | 58, an. 107 | 287—290                  |    |
|                       | s.            | s.                | s.                | 87          | 260                      |    |
|                       | v.s.          | v.s.              | v.s.              | 103—104     | 267—270                  |    |
|                       | v.s.          | v.s.              | v.s.              | 126—126.5   | subl.                    |    |
|                       | v.s.          | v.s.              | v.s.              | 124.5—125   | 276—279                  | 13 |
|                       | h.s.          | v.s.              | v.s.              | 217         | subl.                    | 14 |
|                       | s.            | s.                |                   | 163         | 277—280                  | 15 |
|                       |               | s.                |                   | 27          | 286.5/751                | 16 |
|                       |               | s.                |                   | 40.4        | 284.7/756.5              | 17 |
|                       |               | s.                |                   | 128         | 285                      | 18 |
|                       | v.s.s.        |                   |                   |             | 139—140                  | 19 |
| 0.734/0°              |               |                   |                   |             | 102.5/756                | 20 |
| 0.833/20°             | i.            |                   |                   | liq.        | 164—166/741              | 21 |
| 0.8062/20°            |               |                   |                   | liq.        | 125—126                  | 22 |
| 0.9813/15°            |               |                   |                   |             | 184.1—184.2/<br>755.8mm. | 23 |
| 1.0118/15°            |               |                   |                   |             | 172—173/754mm            | 24 |
| 0.6865/—5.8°          | s             | s.                |                   | liq.        | 7.3                      | 25 |
|                       |               |                   |                   |             | 117                      | 26 |
| 0.9555/20°            |               | s.                |                   | 2.5         | 193.1                    | 27 |
|                       | i.            | s.                |                   | 240         |                          | 28 |
|                       | i.            | s.                |                   | 86          |                          | 29 |
|                       | i.            | s.                |                   | 231—232     |                          | 30 |
|                       | i.            | s.                |                   | 243—244     |                          | 31 |

| Name.                           | Formula.   | Formula Weight. | Empirical Formula. |
|---------------------------------|--|-----------------|--------------------|
| 1 Dimethyl ethyl benzene, 1:3:5 | $C_6H_3(CH_3)_2O_2H_5$   | 134.16          | $C_{10}H_{14}$     |
| 2 — furane, 2:5                 | $C_4H_2O(CH_3)_2$  | 96.09           | $C_6H_8O$          |
| 3 — glyoxime                    | $CH_3.C:(NOH).C:(NOH).CH_3$  | 116.10          | $C_4H_8O_2N_2$     |
| 4 — hydro quinone               | $C_6H_4(OCH_3)_2$  | 138.12          | $C_8H_{10}O_2$     |
| 5 — hypophosphorous acid        | $(CH_3)_2OH.PO$  | 94.11           | $C_2H_7O_2P$       |
| 6 — malonic acid                | $(CH_3)_2:O:(COOH)_2$  | 132.09          | $C_5H_8O_4$        |
| 7 — — anhydride                 | $(CH_3)_2:O:(CO)_2:O$  | 114.07          | $C_5H_6O_3$        |
| 8 — naphthalene, 1:4            | $C_{10}H_6(CH_3)_2$  | 156.16          | $C_{12}H_{12}$     |
| 9 — —, 2:6                      |  | 156.16          | "                  |
| 10 — naphthylamine, $\alpha$    | $C_{10}H_7.N(CH_3)_2$  | 171.17          | $C_{12}H_{13}N$    |
| 11 — —, $\beta$                 |  | 171.17          | "                  |
| 12 — nitrosamine                | $(CH_3)_2:N.NO$  | 74.08           | $C_2H_5ON_2$       |
| 13 — phosphine                  | $(CH_3)_2:PH$  | 62.11           | $C_2H_7P$          |
| 14 — pyrazine                   | $CH \begin{matrix} \diagup C(CH_3).N \\ \diagdown N:C(CH_3) \end{matrix} CH$ | 108.11          | $C_6H_8N_2$        |
| 15 — pyridine, see              | Lutidine   |                 |                    |
| 16 — pyrrole, 2:5               | $C_4H_2N(CH_3)_2$  | 95.11           | $C_6H_8N$          |
| 17 — resorcinol                 | $C_6H_4(OCH_3)_2$  | 138.12          | $C_8H_{10}O_2$     |
| 18 — sulphate                   | $SO_2(OCH_3)_2$  | 126.12          | $C_2H_6O_4S$       |
| 19 — thetine                    | $CH_2.S(SCH_3)_2$  | 120.14          | $C_4H_8O_2S$       |
| 20 — thiophene, 2:3             | $CO.O$   |                 |                    |
| 21 — —, 2:4                     | $C_4H_2S(CH_3)_2$  | 112.15          | $C_6H_8S$          |
| 22 — toluidine, $o$             | " "  | 112.15          | "                  |
| 23 — —, $m$                     | $(CH_3)_2N.C_6H_4.CH_3$  | 135.16          | $C_9H_{13}N$       |
| 24 — —, $p$                     | " "  | 135.16          | "                  |
| 25 — urea, <i>sym.</i>          | " "  | 135.16          | "                  |
| 26 — —, <i>asym.</i>            | $CO:(NH.CH_3)_2$   | 88.10           | $C_3H_8ON_2$       |
| 27 Dinaphthol, $\alpha$         | $(CH_3)_2N.CO.NH_2$  | 88.10           | "                  |
| 28 —, $\beta$                   | $OH.C_{10}H_6.C_{10}H_6.OH$  | 286.21          | $C_{20}H_{14}O_2$  |
| 29 Dinaphthyl                   | " "  | 286.21          | "                  |
| 30 — amine, 2:2'                | $(C_{10}H_7)_2$  | 254.21          | $C_{20}H_{14}$     |
| 31 — ether, 1:1'                | $(C_{10}H_7)_2:NH$   | 269.23          | $C_{20}H_{15}N$    |
| 32 — —, 1:2'                    | $(C_{10}H_7)_2:O$  | 270.21          | $C_{20}H_{14}O$    |
| 33 — —, 2:2'                    | " "  | 270.21          | "                  |
|                                 | " "  | 270.21          | "                  |

| Density<br>$H_2O=1$ . | Solubility in |          |             | M.P.<br>°C. | B.P.<br>°C.        |    |
|-----------------------|---------------|----------|-------------|-------------|--------------------|----|
|                       | Water.        | Alcohol. | Ether.      |             |                    |    |
| 0.861/20°             |               |          |             | -20         | 185                | 1  |
| 0.9026/17.7°          | i.            | m.       | s.          | liq.        | 93                 | 2  |
|                       |               |          |             |             | 243                | 3  |
|                       | i.            |          | s. $C_6H_6$ | 55—56       | 205                | 4  |
|                       | s.            | s.       | s.          | 76          |                    | 5  |
|                       | 1:10/13°      | v.s.     | s.s.        | 184—184.5   |                    | 6  |
| 1.0176/20°            |               |          |             | 140         | d. 170—175         | 7  |
|                       |               |          |             |             | 262—264/<br>751mm. | 8  |
|                       |               |          |             | 110—111     |                    | 9  |
| 1.0423/20°            | i.            | s.       | s.          | liq.        | 274—275/711        | 10 |
|                       |               | s.       |             | 46—47.7     | 305                | 11 |
|                       |               |          |             |             | 148.5/724          | 12 |
| < $H_2O$              | i.            |          |             | liq.        | 25                 | 13 |
| 0.9896/18°            | m.            | m.       | m.          | 15          | 155                | 14 |
|                       |               |          |             |             |                    | 15 |
| 0.9353/19.8°          | v.s.s.        | v.s.     | v.s.        | oil         | 165/752mm.         | 16 |
| 1.0803/0°             | v.s.s.        | s.       | s.          | -17         | 214—215            | 17 |
| 1.3276/20°            |               |          |             | liq.        | 188.3—188.6        | 18 |
|                       | del.          | s.       |             | d.          |                    | 19 |
| 0.9938/21°            |               |          |             | liq.        | 136—137            | 20 |
| 0.9956/20°            |               |          |             |             | 137—138            | 21 |
| 0.9333/15°            |               |          |             |             | 183                | 22 |
|                       |               |          |             |             | 215                | 23 |
|                       |               |          |             |             | 211—211.5          | 24 |
| 0.9424/15°            |               |          |             | 100.5       | 268—273 (corr.)    | 25 |
|                       |               | s.s.     | v.s.s.      | 182—185     |                    | 26 |
|                       | i.            | s.       | s.          | 300         |                    | 27 |
|                       | i.            | s.       | s.          |             |                    | 28 |
|                       |               |          | s.          | 180—182     | subl.              | 29 |
|                       | i.            | s.s.     | s. $C_6H_6$ | 170.5       | 471                | 30 |
|                       | i.            | h.s.     | v.s.        | 109—110     |                    | 31 |
|                       |               |          |             | 81          | 264/15mm.          | 32 |
|                       |               |          |             | 105         | 250/19mm.          | 33 |

| Name.                                 | Formula.                  | Formula Weight. | Empirical Formula. |
|---------------------------------------|---------------------------|-----------------|--------------------|
| 1 Dimethyl ketone, 1:2'               | $(C_{10}H_7)_2:CO$        | 282.22          | $C_{21}H_{14}O$    |
| 2 —, 2:2' $\alpha$ isomer             | " "                       | 282.22          | "                  |
| 3 —, 2:2' $\beta$ isomer              | " "                       | 282.22          | "                  |
| 4 — methane, $\alpha$                 | $(C_{10}H_7)_2:CH_2$      | 268.23          | $C_{21}H_{16}$     |
| 5 —, $\beta$                          | " "                       | 268.23          | "                  |
| 6 Dinicotinic acid, see               | Pyridine carboxylic acid  |                 |                    |
| 7 Dinitro aniline, 1:2:4              | $C_6H_3(NO_2)_2NH_2$      | 183.10          | $C_6H_5O_4N_3$     |
| 8 —, 1:2:6                            | " "                       | 183.10          | "                  |
| 9 — anisole, 1:3:5                    | $(NO_2)_2:C_6H_3.OCH_3$   | 198.10          | $C_7H_6O_5N_2$     |
| 10 — anthraquinone, 1:8               | $C_{14}H_6O_2(NO_2)_2$    | 298.14          | $C_{14}H_6O_6N_2$  |
| 11 —, 2:7                             | " "                       | 298.14          | "                  |
| 12 — benzene, $o$                     | $C_6H_4(NO_2)_2$          | 168.08          | $C_6H_4O_4N_2$     |
| 13 —, $m$                             | " "                       | 168.08          | "                  |
| 14 —, $p$                             | " "                       | 168.08          | "                  |
| 15 — benzoic acid, 1:2:5              | $C_6H_3.COOH(NO_2)_2$     | 212.09          | $C_7H_4O_6N_2$     |
| 16 ———, 1:2:4                         | " "                       | 212.09          | "                  |
| 17 ———, 1:2:6                         | " "                       | 212.09          | "                  |
| 18 ———, 1:3:4                         | " "                       | 212.09          | "                  |
| 19 ———, 1:3:5                         | " "                       | 212.09          | "                  |
| 20 — $p$ cresol                       | $C_6H_2(NO_2)_2(CH_3)OH$  | 198.10          | $C_7H_6O_5N_2$     |
| 21 — dichlor benzene,<br>1:3:2:5      | $C_6H_2(NO_2)_2Cl_2$      | 236.99          | $C_6H_2O_4N_2Cl_2$ |
| 22 — diphenyl, 4:4'                   | $NO_2.C_6H_4.C_6H_4.NO_2$ | 244.14          | $C_{12}H_8O_4N_2$  |
| 23 —, 2:2'                            | " "                       | 244.14          | "                  |
| 24 — diphenylamine, 2:4               | $(C_6H_4.NO_2)_2:NH$      | 259.16          | $C_{12}H_9O_4N_3$  |
| 25 —, 4:4'                            | " "                       | 259.16          | "                  |
| 26 — 1:4 hydroxy benzoic<br>acid, 3:5 | $C_6H_2OH(COOH)(NO_2)_2$  | 228.09          | $C_7H_4O_7N_2$     |
| 27 — methane                          | $CH_2(NO_2)_2$            | 106.04          | $CH_2O_4N_2$       |
| 28 — naphthalene, 1:5                 | $C_{10}H_6(NO_2)_2$       | 218.12          | $C_{10}H_6O_4N_2$  |
| 29 —, 1:8                             | $C_{10}H_6(NO_2)_2$       | 218.12          | $C_{10}H_6O_4N_2$  |
| 30 —, 1:3                             | " "                       | 218.12          | "                  |
| 31 — naphthol, 1:2:4                  | $C_{10}H_5OH(NO_2)_2$     | 234.12          | $C_{10}H_6O_5N_2$  |
| 32 —, 1:2:6                           | " "                       | 234.12          | "                  |
| 33 — phenol, 1:3:4                    | $C_6H_3OH(NO_2)_2$        | 184.08          | $C_6H_4O_5N_2$     |
| 34 —, 1:2:3                           | " "                       | 184.08          | "                  |

| Density<br>H <sub>2</sub> O=1. | Solubility in                |                    |                                      | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|------------------------------|--------------------|--------------------------------------|-------------|-------------|----|
|                                | Water.                       | Alcohol.           | Ether.                               |             |             |    |
|                                |                              | 1: 77              | s., s. C <sub>6</sub> H <sub>6</sub> | 135         |             | 1  |
|                                |                              | 1: 267             |                                      | 125.5       |             | 2  |
|                                | s. CHCl <sub>3</sub>         | 1: 1250            | v.s.s.                               | 164.5       |             | 3  |
|                                | s. CHCl <sub>3</sub>         | h. 1: 15           | s., s. C <sub>6</sub> H <sub>6</sub> | 109         | >360        | 4  |
|                                |                              | s.                 | s. C <sub>6</sub> H <sub>6</sub>     | 93          |             | 5  |
|                                |                              |                    |                                      |             |             | 6  |
| 1.615/14°                      | h.v.s.s.                     | s.                 |                                      | 181         |             | 7  |
|                                |                              | h.s.s.             |                                      | 138—139     |             | 8  |
|                                |                              |                    |                                      | 204         |             | 9  |
|                                | v.s.s.                       | v.s.s.             | v.s.s.                               | 256—260     | subl. d.    | 10 |
|                                | s.h. acetic                  | s.s.               | s.s.                                 | 280         |             | 11 |
| 1.565/17°                      | 0.38:100<br>/100°            | 3.8: 100<br>/25°   |                                      | 116.5       | 319/773.5   | 12 |
| 1.546/14°                      | i.                           | 5.9: 100<br>/24.6° |                                      | 89.7        | 302.8       | 13 |
| 1.587/17°                      | 0.18:100<br>/100°            | h.s.               |                                      | 171—172     | 299/773mm.  | 14 |
|                                | h.s.s.                       | v.s.               | s. C <sub>6</sub> H <sub>6</sub>     | 177         |             | 15 |
| 1.672                          |                              |                    |                                      | 180         |             | 16 |
| 1.681                          | h.v.s.                       |                    |                                      | 202         | d.          | 17 |
| 1.674                          | 0.673:100/25°                | s.s.               | s.s.                                 | 163—164     |             | 18 |
|                                | h.s.                         | s.                 | s.s.                                 | 206         |             | 19 |
|                                |                              |                    |                                      | 84          |             | 20 |
|                                |                              |                    |                                      | 104         | 312 d.      | 21 |
|                                |                              |                    |                                      |             |             | 22 |
|                                |                              | c.s.s.             |                                      | 233         |             | 22 |
|                                |                              | h.s.               |                                      | 93.5        |             | 23 |
|                                |                              |                    |                                      | 153         |             | 24 |
|                                |                              | s.                 |                                      | 214         |             | 25 |
|                                |                              |                    |                                      | 248.5—249.5 |             | 26 |
|                                |                              |                    |                                      |             |             | 27 |
|                                |                              | s.s.               | s. C <sub>6</sub> H <sub>6</sub>     | 216         | d.          | 27 |
|                                |                              | s.s.               | s.s. C <sub>6</sub> H <sub>6</sub>   | 170         | subl.       | 28 |
|                                | 1: 100,<br>CHCl <sub>3</sub> |                    |                                      |             | d.          | 29 |
|                                |                              | s.                 |                                      | 144         | subl.       | 30 |
|                                | h.v.s.s.                     | s.                 | s., s. acetic                        | 143         |             | 31 |
|                                | h.v.s.                       | v.s.               | v.s.                                 | 195 d.      |             | 32 |
|                                | h. 1: 21                     | c.v.s.s.           | s.                                   | 134         |             | 33 |
|                                | s.s.                         | h.s.               | s.                                   | 144         |             | 34 |

| Name.                         | Formula.  | Formula Weight. | Empirical Formula. |
|-------------------------------|---|-----------------|--------------------|
| 1 Dinitro phenol, 1:2:4       | $C_6H_3OH(NO_2)_2$  | 184.08          | "                  |
| 2 —, 1:2:5                    | " "   | 184.08          | "                  |
| 3 —, 1:2:6                    | " "   | 184.08          | "                  |
| 4 —resorcinol, 2:4            | $C_6H_2(NO_2)_2(OH)_2$  | 200.08          | $C_6H_4O_6N_2$     |
| 5 —salicylic acid, 3:5        | $C_6H_2OH(COOH)(NO_2)_2 \cdot H_2O$                                     | 246.11          | $C_6H_4O_7N_2$     |
| 6 —toluene, 1:2:4             | $C_6H_3(CH_3)(NO_2)_2$  | 182.10          | $C_7H_8O_4N_2$     |
| 7 —, 1:2:6                    | " "   | 182.10          | "                  |
| 8 —, 1:3:4                    | " "   | 182.10          | "                  |
| 9 —, 1:3:5                    | " "   | 182.10          | "                  |
| 10 —xylene, 1:3:4:6           | $C_6H_2(CH_3)_2(NO_2)_2$  | 196.12          | $C_8H_8O_4N_2$     |
| 11 —, 1:4:2:6                 | " "   | 196.12          | "                  |
| 12 —, 1:4:2:3                 | " "   | 196.12          | "                  |
| 13 Dioctyl, see               | Hexadecane  |                 |                    |
| 14 Dioxindole                 | $C_6H_4 \begin{array}{c} \diagup CH(OH) \\ \diagdown NH \end{array} CO$ | 149.11          | $C_8H_7O_2N$       |
| 15 Diphenic acid              | $(C_6H_4COOH)_2$  | 242.15          | $C_{14}H_{10}O_4$  |
| 16 Diphenol, 3:3'             | $OH.C_6H_4.C_6H_4.OH$   | 186.14          | $C_{12}H_{10}O_2$  |
| 17 —, 2:2'                    | " "   | 186.14          | "                  |
| 18 —4:4'                      | " "   | 186.14          | "                  |
| 19 Diphenyl                   | $(C_6H_5)_2$  | 154.14          | $C_{12}H_{10}$     |
| 20 —acetamidine               | $CH_3.C(N.OH_5).NH.OH_5$  | 210.20          | $C_{14}H_{14}N_2$  |
| 21 —acetic acid               | $(C_6H_5)_2:CH.COOH$  | 212.17          | $C_{14}H_{12}O_2$  |
| 22 —amine                     | $(C_6H_5)_2:NH$   | 169.16          | $C_{13}H_{11}N$    |
| 23 —benzene, <i>p</i>         | $C_6H_4(C_6H_5)_2$  | 230.20          | $C_{18}H_{14}$     |
| 24 —carbonate                 | $(C_6H_5O)_2CO$   | 214.15          | $C_{13}H_{10}O_3$  |
| 25 —carboxylic acid, <i>o</i> | $C_6H_5.C_6H_4.COOH$  | 198.15          | $C_{13}H_{10}O_2$  |
| 26 —, <i>p</i>                | " "   | 198.15          | "                  |
| 27 —diacetylene               | $C_6H_5.C:C:C:C_6H_5$   | 202.16          | $C_{16}H_{10}$     |
| 28 —dicarboxylic acid, 2:2"   | $(C_6H_4)_2(COOH)_2$  | 242.15          | $C_{14}H_{10}O_4$  |
| 29 —ethane, $\alpha\alpha$    | $CH_3.CH:(C_6H_5)_2$  | 182.18          | $C_{14}H_{14}$     |
| 30 —ether, see                | Phenyl ether  |                 |                    |
| 31 —ethylene diamine,         | $NC_2H_4(C_6H_5.NH)_2$  | 212.21          | $C_{14}H_{16}N_2$  |
| 32 —formamidine               | $C_2H_2N:CH.NH.C_6H_5$  | 196.18          | $C_{13}H_{12}N_2$  |
| 33 —hydrazine                 | $(C_6H_5)_2:N.NH_2$   | 184.18          | $C_{12}H_{12}N_2$  |
| 34 —methane                   | $(C_6H_5)_2:CH_2$   | 168.16          | $C_{13}H_{12}$     |

| Density<br>H <sub>2</sub> O=1. | Solubility in                      |                         |                                  | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|------------------------------------|-------------------------|----------------------------------|-------------|-------------|----|
|                                | Water.                             | Alcohol.                | Ether.                           |             |             |    |
| .683/24°                       |                                    |                         |                                  | 113—114     |             | 1  |
|                                |                                    |                         |                                  | 105         |             | 2  |
| .724                           |                                    |                         |                                  | 63—64       |             | 3  |
|                                |                                    | s                       |                                  | 142         | subl.       | 4  |
|                                | h v.s.                             | s                       | s.                               | an. 172—173 | subl.       | 5  |
|                                | i.                                 | s.s.                    | s.s. OS <sub>2</sub>             | 70.2        |             | 6  |
| .539                           |                                    | s.                      |                                  | 66          |             | 7  |
| .32                            | i.                                 | s.s.                    | 2.19 : 100,<br>OS <sub>2</sub>   | 69.5—71     |             | 8  |
|                                | s.s.                               | c.s.                    | s.                               | 88—91       |             | 9  |
|                                |                                    | h.s.                    |                                  | 93          |             | 10 |
|                                |                                    | s.s.                    |                                  | 124         |             | 11 |
|                                |                                    | s.                      |                                  | 90          |             | 12 |
|                                |                                    |                         |                                  |             |             | 13 |
|                                | c. 1 : 12,<br>h. 1 : 6             | c. 1 : 15,<br>h. 1 : 10 | s. alk.                          | 180         | d. 195      | 14 |
|                                | h.s.                               | v.s.                    | v.s.                             | 228—229     | subl.       | 15 |
|                                | h.s.                               | s.                      | s.                               | 123.5       |             | 16 |
|                                | v.s.s.                             | s.                      | s.                               | 98          | 315/768mm.  | 17 |
|                                | s.s.                               | s.                      | s.                               | 272         |             | 18 |
| 1.165                          | c. 6.7 : 100                       | c. 10 : 100             | s.                               | 70.5        | 254.9       | 19 |
|                                | m.                                 | m.                      | m.                               | 134         |             | 20 |
|                                | h.s.                               | s.                      | s.                               | 148         | 268—271     | 21 |
| 1.159                          | s.s.                               | 56 : 100<br>/19.5°      | s.                               | 54          | 302         | 22 |
|                                | h.s. C <sub>6</sub> H <sub>6</sub> | h.s.s.                  | s.                               | 205         | subl.       | 23 |
|                                | i.                                 | h.s.                    | s.                               | 78          | 301—302     | 24 |
|                                | h.s.s.                             | h.s.                    |                                  | 110—111     |             | 25 |
|                                | h.v.s.s.                           | s.                      | s.                               | 224         | subl.       | 26 |
|                                |                                    | s.                      | s.                               | 88          |             | 27 |
|                                | i.                                 | i.                      | i.                               | 228—229     | d.          | 28 |
|                                |                                    |                         |                                  | oil         | 286         | 29 |
|                                |                                    |                         |                                  |             |             | 30 |
|                                | i.                                 | s.                      | s.                               | 65          |             | 31 |
|                                | s.s.                               | s.                      | s. C <sub>6</sub> H <sub>6</sub> | 138—139     |             | 32 |
|                                | s.s.                               | s.                      | s.                               | 127         | 220/50mm.   | 33 |
| 1.0126/11°                     | s. CHCl <sub>3</sub>               | s.                      | s.                               | 27          | 260—261     | 34 |

| Name.                           | Formula.  | Formula Empirical<br>Weight. Formula. |
|---------------------------------|---|---------------------------------------|
| 1 Diphenyl nitrosamine,         | see Nitroso diphenylamine   |                                       |
| 2 — sulphide                    | $(C_6H_5)_2S$   | 186.20 $C_{12}H_{10}S$                |
| 3 — sulphone                    | $(C_6H_5)_2SO_2$  | 218.20 $C_{12}H_{10}O_2S$             |
| 4 — thiocyanate, <i>iso</i> .   | $C_{12}H_9N.CS$   | 211.21 $C_{13}H_9NS$                  |
| 5 — thiourea, <i>sym.</i> , see | Thiocarbanilide   |                                       |
| 6 — tolylmethane                | $(C_6H_5)_2.CH.(C_6H_4.CH_3)$   | 258.24 $C_{20}H_{18}$                 |
| 7 — urea, <i>asym.</i>          | $NH_2.CO.N(C_6H_5)_2$   | 212.18 $C_{13}H_{12}ON_2$             |
| 8 — urea, <i>sym.</i> , see     | Carbanilide   |                                       |
| 9 Diphenylene oxide             | $(C_6H_4)_2:O$  | 168.12 $C_{12}H_8O$                   |
| 10 — ketone, see                | Fluorenone  |                                       |
| 11 Diphenylol, <i>p</i>         | $C_6H_5.C_6H_4OH$   | 170.14 $C_{12}H_{10}O$                |
| 12 Dipicolinic acid, see        | Pyridine carboxylic acid  |                                       |
| 13 Dipropyl amine, <i>norm.</i> | $(C_3H_7)_2:NH$   | 101.16 $C_6H_{15}N$                   |
| 14 — ketone, <i>norm.</i> , see | Butyrene  |                                       |
| 15 Dipyridine                   | $C_{10}H_{10}N_2$   | 158.15 $C_{10}H_{10}N_2$              |
| 16 Dipyridyl, 4:4'              | $C_5H_4N.C_5H_4N$   | 156.13 $C_{10}H_8N_2$                 |
| 17 Diquinoline                  | $C_{18}H_{14}N_2$   | 258.22 $C_{18}H_{14}N_2$              |
| 18 Diquinonyl, 6:6'             | $C_{18}H_{12}N_2$   | 256.21 $C_{18}H_{12}N_2$              |
| 19 —, 2:7'                      | "   | 256.21 "                              |
| 20 Diresorcinol, 3:5:3':5'      | $(OH)_2C_6H_3.O_6H_3(OH)_2.2H_2O$   | 254.17 $C_{12}H_{10}O_4$              |
| 21 Dithio carbamic acid         | $NH_2.CS_2H$  | 93.16 $CH_3NS_2$                      |
| 22 — glycerin, see              | Glycerin mercaptan  |                                       |
| 23 Ditolyl                      | $(C_6H_4.CH_3)_2$   | 182.18 $C_{14}H_{14}$                 |
| 24 — amine                      | $(C_6H_4.CH_3)_2:NH$  | 197.20 $C_{14}H_{15}N$                |
| 25 Diurea                       | $CO \begin{array}{c} \diagup NH.NH \diagdown \\ \diagdown NH.NH \diagup \end{array} CO$ | 116.08 $C_2H_4O_2N_4$                 |
| 26 Dodecane                     | $C_{12}H_{26}$  | 170.27 $C_{12}H_{26}$                 |
| 27 Dodecylene                   | $C_{12}H_{24}$  | 168.25 $C_{12}H_{24}$                 |
| 28 Dulcitol                     | $C_6H_8(OH)_6$  | 182.14 $C_6H_{14}O_6$                 |
| 29 Durene, 1:2:4:5              | $C_6H_2(CH_3)_4$  | 134.16 $C_{10}H_{14}$                 |
| 30 Eicosane                     | $C_{20}H_{42}$  | 282.44 $C_{20}H_{42}$                 |
| 31 Elæo-margaric acid           | $C_{17}H_{30}O_2$   | 266.33 $C_{17}H_{30}O_2$              |
| 32 — stearic acid               | "   | 266.33 "                              |
| 33 Elaidic acid                 | $C_{17}H_{33}COOH$  | 282.36 $C_{18}H_{34}O_2$              |
| 34 Ellagic acid                 | $CO.C_6H(OH)_2.O$   | 338.15 $C_{14}H_6O_8$                 |
|                                 | $O.C_6H(OH)_2.CO$   |                                       |
| 35 Emodin                       | $C_{14}H_4O_2(CH_3)(OH)_3.H_2O$   | 288.18 $C_{15}H_{10}O_5$              |



| Density<br>$H_2O=1.$ | Solubility in |          |                 | M.P.<br>°C. | B.P.<br>°C. |    |
|----------------------|---------------|----------|-----------------|-------------|-------------|----|
|                      | Water.        | Alcohol. | Ether.          |             |             |    |
| 1.12/0°              | i.            | s.       | m.              | liq.        | 296/765mm.  | 1  |
|                      | h.s.s.        | h.s.     | s., s. $C_6H_6$ | 124.5       | 376.4/722   | 2  |
|                      |               |          | v.s.            | 58          |             | 3  |
|                      |               |          |                 |             |             | 4  |
|                      |               |          |                 |             |             | 5  |
|                      | s. $C_6H_6$   | c.s.s.   | s.              | 59—59.5     | >360        | 6  |
|                      |               |          |                 | 187—188     |             | 7  |
|                      |               |          |                 |             |             | 8  |
|                      | i.            | v.s.     | s.              | 85          | 287         | 9  |
|                      |               |          |                 |             |             | 10 |
|                      |               | v.s.     | v.s.            | 161—162     | 305—308     | 11 |
|                      |               |          |                 |             |             | 12 |
| 0.7430/15°           | 5:100/19°     |          |                 |             | 110—111     | 13 |
|                      |               |          |                 |             |             | 14 |
|                      | h.s.          | s.       | s.              | 108         | subl.       | 15 |
|                      | h.v.s.        | v.s.     | v.s.            | 111—112     | 304.8       | 16 |
|                      | i.            | h.s.     | s.              | 114         |             | 17 |
|                      |               | s.       |                 | 178         |             | 18 |
|                      | i.            | h.s.     | s.s.            | 192.5       | subl.       | 19 |
|                      | h.v.s.        |          | s.              | 310         |             | 20 |
|                      | v.s.          | v.s.     | v.s.            |             |             | 21 |
|                      |               |          |                 |             |             | 22 |
|                      | h.s.          | s.       | s.              | 5—7         | 286         | 23 |
|                      |               |          |                 | liq.        | 312/727.5   | 24 |
| 0.9172/121°          |               |          |                 |             |             | 25 |
|                      | c.s.s.        | h.s.s.   |                 | 270         |             | 25 |
| 0.7584/15°           |               |          |                 | - 12        | 214         | 26 |
| 0.7620/15°           |               |          |                 | - 31        | 96/15mm.    | 27 |
| 1.466/15°            | 1:39/15°      | s.s.     |                 | 188.5       | 275—280     | 28 |
|                      |               | s.       | s.              | 79—80       | 190         | 29 |
| 0.777/37°            |               |          |                 | 37          | 205/15mm.   | 30 |
|                      |               | s.       | v.s.s.          | 48          |             | 31 |
|                      |               | s.       | v.s.            | 71          |             | 32 |
|                      |               | v.s.     | s.              | 54          |             | 33 |
|                      |               |          | i.              | d.          |             | 34 |
| 1.667/18°            | h.v.s.s.      | s.s.     |                 |             |             |    |
|                      |               |          |                 |             |             |    |
|                      | s.            | s.       | s. acetic.      | 256—257     |             | 35 |

| Name.                              | Formula.   | Formula Weight. | Empirical Formula.                          |
|------------------------------------|--|-----------------|---|
| 1 Epibromhydrin, $\alpha$          | $\text{CH}_2\text{O}.\text{CH}.\text{CH}_2\text{Br}$                                   | 136.98          | $\text{C}_3\text{H}_5\text{OBr}$            |
| 2 Epichlorhydrin, $\alpha$         | $\text{CH}_2\text{O}.\text{CH}.\text{CH}_2\text{Cl}$                                   | 92.52           | $\text{C}_3\text{H}_5\text{OCl}$            |
| 3 —, $\beta$                       | $\text{O}.\text{CH}_2.\text{CHCl}.\text{CH}_2$   | 92.52           | „   |
| 4 Epicyanhydrin                    | $\text{C}^3\text{H}^5\text{OCN}$   | 83.07           | $\text{C}^4\text{H}^5\text{ON}$             |
| 5 Epi-iodohydrin                   | $\text{C}^3\text{H}^5\text{OI}$  | 183.98          | $\text{C}^4\text{H}^5\text{OI}$             |
| 6 Erucic acid                      | $\text{C}^{22}\text{H}^{42}\text{O}_2$   | 338.45          | $\text{C}^{22}\text{H}^{42}\text{O}_2$      |
| 7 Erythrin                         | $\text{C}^4\text{H}^8\text{O}_4(\text{C}^8\text{H}_7\text{O}_3)_2.2\text{H}_2\text{O}$ | 431.28          | $\text{C}^{20}\text{H}^{22}\text{O}^{10}$   |
| 8 Erythrite, <i>meso</i> .         | $\text{C}^4\text{H}^8(\text{OH})_4$  | 122.10          | $\text{C}^4\text{H}^{10}\text{O}^4$         |
| 9 Ethane                           | $\text{C}_2\text{H}_6$   | 30.06           | $\text{C}_2\text{H}_6$                      |
| 10 Ether, see                      | Ethyl ether  |                 |   |
| 11 Ethenyl triethyl ether          | $\text{CH}_3.\text{C}(\text{OC}_2\text{H}_5)_3$  | 162.18          | $\text{C}^8\text{H}^{18}\text{O}_3$         |
| 12 — tricarboxylic acid            | $\text{C}^2\text{H}_3(\text{COOH})_3$  | 162.07          | $\text{C}^5\text{H}^6\text{O}_6$            |
| 13 Ethyl acetamide                 | $\text{CH}_3.\text{CO}.\text{NH}.\text{C}_2\text{H}_5$                                 | 87.10           | $\text{C}^5\text{H}^9\text{ON}$             |
| 14 — acetoacetic acid, ethyl ester | $\text{CH}_3\text{CO}.\text{CH}(\text{C}_2\text{H}_5)\text{COOC}_2\text{H}_5$          | 158.15          | $\text{C}^8\text{H}^{14}\text{O}_3$         |
| 15 — acetylene                     | $\text{C}_2\text{H}_2$   | 54.07           | $\text{C}_2\text{H}_2$                      |
| 16 — alcohol                       | $\text{C}_2\text{H}_5\text{OH}$  | 46.06           | $\text{C}^2\text{H}^6\text{O}$              |
| 17 — amine                         | $\text{C}_2\text{H}_5.\text{NH}_2$   | 45.08           | $\text{C}^2\text{H}^7\text{N}$              |
| 18 — amino benzoic acid, <i>m</i>  | $\text{C}_2\text{H}_5.\text{NH}.\text{C}_6\text{H}_4.\text{COOH}$                      | 165.14          | $\text{C}^9\text{H}^{11}\text{O}_2\text{N}$ |
| 19 — phenol, <i>p</i>              | $\text{C}_2\text{H}_5.\text{NH}.\text{C}_6\text{H}_4\text{OH}$                         | 137.14          | $\text{C}^8\text{H}^{11}\text{ON}$          |
| 20 — aniline                       | $\text{C}_6\text{H}_5.\text{NH}.\text{C}_2\text{H}_5$                                  | 121.14          | $\text{C}^8\text{H}^{11}\text{N}$           |
| 21 — anthracene                    | $\text{C}^{14}\text{H}_{10}$   | 206.19          | $\text{C}^{14}\text{H}_{10}$                |
| 22 —, dihydro                      | $\text{C}^{14}\text{H}_{12}$   | 208.21          | $\text{C}^{16}\text{H}^{14}$                |
| 23 — benzene                       | $\text{C}_6\text{H}_6$   | 106.12          | $\text{C}^6\text{H}^6$                      |
| 24 — benzoic acid, <i>o</i>        | $\text{C}_6\text{H}_5.\text{C}_2\text{H}_5.\text{COOH}$                                | 150.13          | $\text{C}^9\text{H}^{10}\text{O}_2$         |
| 25 — —, <i>m</i>                   | „ „  | 150.13          | „   |
| 26 — —, <i>p</i>                   | „ „  | 150.13          | „   |
| 27 — benzyl aniline                | $(\text{C}_2\text{H}_5)(\text{C}_7\text{H}_7):\text{N}.\text{C}_6\text{H}_5$           | 211.22          | $\text{C}^{15}\text{H}^{17}\text{N}$        |
| 28 — borate                        | $(\text{C}_2\text{H}_5)_3\text{BO}_3$  | 146.0           | $\text{C}^6\text{H}^{15}\text{O}_3\text{B}$ |
| 29 — bromide                       | $\text{C}_2\text{H}_5\text{Br}$  | 108.97          | $\text{C}^2\text{H}^5\text{Br}$             |
| 30 — carbazole                     | $\text{C}^{12}\text{H}_8\text{N}.\text{C}_2\text{H}_5$                                 | 195.18          | $\text{C}^{14}\text{H}^{13}\text{N}$        |
| 31 — carbonate                     | $\text{CO}(\text{OC}_2\text{H}_5)_2$   | 118.11          | $\text{C}^5\text{H}^{10}\text{O}_3$         |
| 32 — carbostyryl                   | $\text{C}_6\text{H}_4.\text{C}_2\text{H}(\text{C}_2\text{H}_5).\text{NH}.\text{CO}$    | 174.16          | $\text{C}^{11}\text{H}^{11}\text{ON}$       |
| 33 — carbylamine                   | $\text{C}_2\text{H}_5.\text{NC}$   | 55.07           | $\text{C}^3\text{H}^5\text{N}$              |
| 34 — chloride                      | $\text{C}_2\text{H}_5\text{Cl}$  | 64.51           | $\text{C}^2\text{H}^5\text{Cl}$             |
| 35 — chloroformate                 | $\text{Cl}.\text{COO}.\text{C}_2\text{H}_5$  | 108.56          | $\text{C}_3\text{H}_5\text{O}_2\text{Cl}$   |

| Density<br>$H_2O=1.$ | Solubility in |          |               | M.P.<br>°C. | B.P.<br>°C.   |    |
|----------------------|---------------|----------|---------------|-------------|---------------|----|
|                      | Water.        | Alcohol. | Ether.        |             |               |    |
| 1.615/14°            |               |          |               |             | 138—140       | 1  |
| 1.2040/0°            | i.            |          |               | liq.        | 116.5/761     | 2  |
|                      |               |          |               |             | 132—134       | 3  |
|                      | h.s.          | s.       |               | 162         |               | 4  |
| 1.03/13°             | i.            |          |               |             | 160—180       | 5  |
|                      |               | v.s.     |               | 33—34       | 281/30mm.     | 6  |
|                      | v.s.s.        | s.       | l : 328       | an. 145     |               | 7  |
| 1.452/17°            | v.s.          | s.s.     | i.            | 120         | 330           | 8  |
|                      | s.s.          | s.       |               | gas         | - 89/735      | 9  |
|                      |               |          |               |             |               | 10 |
| 0.94/22°             | h.d.          |          |               |             | 142           | 11 |
|                      | s.            | s.       | s.            | d. 159      |               | 12 |
|                      |               |          | s. ac.        |             | 205           | 13 |
| 0.9834/16°           | i.            |          |               |             | 195—196       | 14 |
|                      |               |          |               | liq.        | 18            | 15 |
| 0.7937/15°           | m.            |          | m.            | - 117.6     | 77.8/753      | 16 |
| 0.6994/8°            | m.            | m.       | m.            | - 85.2      | 16.55         | 17 |
|                      | h.s.s.        | m.       | m.            | 112         |               | 18 |
|                      | i.            | v.s.     | h.s. $C_6H_6$ | 70          | 330           | 19 |
| 0.9625/20°           |               |          |               | - 80        | 205—207       | 20 |
|                      | i.            | s.       |               | 60—61       |               | 21 |
| 1.049/18°            | i.            | m.       | m.            | oil.        | 320—323 d.    | 22 |
| 0.8759/20°           | i.            | m.       | m.            | - 92.8      | 135.8/758     | 23 |
| 1.050/15°            | h.s.          | s.       | s.            | 68          | subl.         | 24 |
|                      | s.            | s.       |               | 47          |               | 25 |
|                      | h.s.          | s.       | s.            | 112         |               | 26 |
|                      | i.            | s.s.     | s.s.          |             | 285—286/710mm | 27 |
| 0.887/0°             |               |          |               |             | 121           | 28 |
| 1.450/15°            | s.s.          | m.       | m             | - 116       | 38.4          | 29 |
|                      |               | h.s.     | v.s.          | 67—68       |               | 30 |
| 0.9762/20°           | i.            | s.       |               | liq.        | 126.4         | 31 |
|                      |               |          |               | 168         |               | 32 |
| 0.7591/4°            |               |          |               | liq.        | 78            | 33 |
| 0.921/0°             | 2 : 100       | m.       | m             | - 141.6     | 12.5          | 34 |
| 1.139/15°            | d.            |          |               | liq.        | 94            | 35 |

| Name.  | Formula.  | Formula Weight. | Empirical Formula.                          |
|--|---|-----------------|---|
| 1 Ethyl crotonic acid                            | $\text{CH}_3\text{C}_2\text{H}(\text{C}_2\text{H}_5)\text{COOH}$        | 114.11          | $\text{C}_6\text{H}_{10}\text{O}_2$         |
| 2 — cyanate                                      | $\text{N} : \text{C}.\text{OC}_2\text{H}_5$                             | 71.07           | $\text{C}_3\text{H}_5\text{ON}$             |
| 3 —, <i>iso</i>                                  | $\text{CO} : \text{N}.\text{C}_2\text{H}_5$                             | 71.07           | „   |
| 4 — diphenylamine                                | $(\text{C}_6\text{H}_5)_2 : \text{N}.\text{C}_2\text{H}_5$              | 197.20          | $\text{C}_{14}\text{H}_{15}\text{N}$        |
| 5 — diphenylphosphine                            | $(\text{C}_6\text{H}_5)_2 : \text{P}.\text{C}_2\text{H}_5$              | 214.23          | $\text{C}_{14}\text{H}_{15}\text{P}$        |
| 6 — disulphide                                   | $(\text{C}_2\text{H}_5)_2 : \text{S}$                                   | 122.22          | $\text{C}_4\text{H}_{10}\text{S}_2$         |
| 7 — dithiocarbonate                              | $\text{CO} : (\text{SC}_2\text{H}_5)_2$                                 | 150.23          | $\text{C}_4\text{H}_{10}\text{OS}_2$        |
| 8 — ether  | $\text{C}_2\text{H}_5.\text{O}.\text{C}_2\text{H}_5$                    | 74.10           | $\text{C}_4\text{H}_{10}\text{O}$           |
| 9 — fluoride                                     | $\text{C}_2\text{H}_5\text{F}$  | 48.05           | $\text{C}_2\text{H}_5\text{F}$              |
| 10 — formamide                                   | $\text{CHO}.\text{NH}(\text{C}_2\text{H}_5)$                            | 73.08           | $\text{C}_3\text{H}_7\text{ON}$             |
| 11 — glycine                                     | $\text{CH}_2(\text{NH}.\text{C}_2\text{H}_5)\text{COOH}$                | 103.10          | $\text{C}_3\text{H}_7\text{O}_2\text{N}$    |
| 12 — glycollic acid                              | $\text{CH}_2(\text{O}.\text{C}_2\text{H}_5)\text{COOH}$                 | 104.08          | $\text{C}_4\text{H}_8\text{O}_3$            |
| 13 — hydrazine                                   | $\text{C}_2\text{H}_5.\text{NH}.\text{NH}_2$                            | 60.09           | $\text{C}_2\text{H}_8\text{N}_2$            |
| 14 — hydrogen sulphate, see Ethyl sulphuric acid |   |                 |   |
| 15 — hydroxylamine $\beta$                       | $\text{C}_2\text{H}_5.\text{NHOH}$                                      | 61.08           | $\text{C}_2\text{H}_7\text{ON}$             |
| 16 — isoamyl ether                               | $\text{C}_2\text{H}_5.\text{O}.\text{C}_5\text{H}_{11}$                 | 116.16          | $\text{C}_7\text{H}_{16}\text{O}$           |
| 17 — isobutyl ether                              | $\text{C}_2\text{H}_5.\text{O}.\text{C}_4\text{H}_9$                    | 102.14          | $\text{C}_6\text{H}_{14}\text{O}$           |
| 18 — isocyanide                                  | $\text{C}_2\text{H}_5.\text{NC}$  | 55.07           | $\text{C}_2\text{H}_5\text{N}$              |
| 19 — isopropyl ether                             | $\text{C}_2\text{H}_5.\text{O}.\text{C}_3\text{H}_7$                    | 88.12           | $\text{C}_5\text{H}_{12}\text{O}$           |
| 20 — iodide                                      | $\text{C}_2\text{H}_5\text{I}$  | 155.97          | $\text{C}_2\text{H}_5\text{I}$              |
| 21 — malonic acid                                | $\text{C}_2\text{H}_5.\text{CH}(\text{COOH})_2$                         | 150.11          | $\text{C}_5\text{H}_8\text{O}_4$            |
| 22 — mercaptan                                   | $\text{C}_2\text{H}_5.\text{SH}$  | 62.12           | $\text{C}_2\text{H}_6\text{S}$              |
| 23 — methyl acetic acid                          | $\text{C}_2\text{H}_5.\text{CH}(\text{CH}_3).\text{COOH}$               | 102.11          | $\text{C}_5\text{H}_{10}\text{O}_2$         |
| 24 — benzene, <i>o</i>                           | $\text{C}_2\text{H}_5.\text{C}_6\text{H}_4.\text{CH}_3$                 | 120.14          | $\text{C}_9\text{H}_{12}$                   |
| 25 — —, <i>m</i>                                 | „ „   | 120.14          | „   |
| 26 — —, <i>p</i>                                 | „ „   | 120.14          | „   |
| 27 — ether                                       | $\text{C}_2\text{H}_5.\text{O}.\text{CH}_3$                             | 60.08           | $\text{C}_3\text{H}_8\text{O}$              |
| 28 — glyoxalin                                   | $\text{C}_4\text{H}_5.\text{N}.\text{C}_2\text{H}_5$                    | 110.13          | $\text{C}_6\text{H}_{10}\text{N}_2$         |
| 29 — ketone                                      | $\text{C}_2\text{H}_5.\text{CO}.\text{CH}_3$                            | 72.08           | $\text{C}_4\text{H}_8\text{O}$              |
| 30 — protocatechuic aldehyde                     | $\text{C}_6\text{H}_3(\text{CHO})(\text{OCH}_3)(\text{OC}_2\text{H}_5)$ | 180.15          | $\text{C}_{10}\text{H}_{12}\text{O}_3$      |
| 31 — sulphide                                    | $\text{C}_2\text{H}_5.\text{S}.\text{CH}_3$                             | 76.14           | $\text{C}_3\text{H}_8\text{S}$              |
| 32 — monothio carbonate                          | $\text{CS}(\text{OC}_2\text{H}_5)_2$                                    | 134.17          | $\text{C}_5\text{H}_{10}\text{O}_2\text{S}$ |
| 33 — naphthalene, $\alpha$                       | $\text{C}_{10}\text{H}_7.\text{C}_2\text{H}_5$                          | 156.16          | $\text{C}_{12}\text{H}_{12}$                |
| 34 —, $\beta$                                    | „ „   | 156.16          | „   |
| 35 — naphthylamine, $\alpha$                     | $\text{C}_{10}\text{H}_7.\text{NH}.\text{C}_2\text{H}_5$                | 171.17          | $\text{C}_{12}\text{H}_{13}\text{N}$        |
| 36 —, $\beta$                                    | „ „   | 171.17          | „   |
| 37 — naphthyl ether, $\alpha$                    | $\text{C}_{10}\text{H}_7.\text{O}.\text{C}_2\text{H}_5$                 | 172.16          | $\text{C}_{12}\text{H}_{14}\text{O}$        |
| 38 — —, $\beta$                                  | $\text{C}_{10}\text{H}_7.\text{O}.\text{C}_2\text{H}_5$                 | 172.16          | $\text{C}_{12}\text{H}_{12}\text{O}$        |
| 39 — nitrate                                     | $\text{C}_2\text{H}_5.\text{NO}_3$                                      | 91.06           | $\text{C}_2\text{H}_5\text{O}_3\text{N}$    |

| Density<br>at 20°=1. | Solubility in |             |             | M.P.<br>°C. | B.P.<br>°C.    |    |
|----------------------|---------------|-------------|-------------|-------------|----------------|----|
|                      | Water.        | Alcohol.    | Ether.      |             |                |    |
|                      | v.s.s.        | s.          |             | 39.5        | subl.          | 1  |
| 0.89                 | i.            |             |             | liq.        | d.             | 2  |
| 0.8981               | h.s.          | s.          | s.          |             | 60             | 3  |
|                      |               | s.          |             | liq.        | 285—287        | 4  |
|                      |               | s.          | s. $C_6H_6$ | liq.        | 293            | 5  |
| 0.933/20°            | v.s.s.        |             |             |             | 153/730        | 6  |
| 1.085/19°            |               |             |             |             | 196—197        | 7  |
| 0.7201/15°           | 1 : 12/17.5°  | m.          |             | - 117.6     | 34.6           | 8  |
| 1.7                  | s.            | v.s. (abs.) |             |             | - 32           | 9  |
| 0.952/21°            |               |             |             |             | 199            | 10 |
|                      | s.            | s.          |             | d. > 160    |                | 11 |
|                      |               |             |             | liq.        | 206—207        | 12 |
| -                    | v.s.          | v.s.        | s.          |             | 99.5/709       | 13 |
|                      |               |             |             |             |                | 14 |
| 0.8827/7.5°          | m.            | m.          | m.          |             | 59—60          | 15 |
| 0.764/18°            |               |             |             |             | 112            | 16 |
| 0.7507               |               |             |             |             | 79             | 17 |
| 0.7591/4°            | v.s.          |             |             |             | 78.1           | 18 |
| 0.7447/0°            |               |             |             |             | 54             | 19 |
| 1.9433/15°           | s.s.          | s.          | s.          | - 108.5     | 72.3           | 20 |
|                      | 53 : 100/0°   | s.          | s.          | 110         | 160 d.         | 21 |
| 0.8391/20°           | 1.5 : 100     | s.          |             | - 22        | 35.5—36.1      | 22 |
| 0.938/24°            |               |             |             | liq.        | 175            | 23 |
| 0.873/16°            | i.            | s.          | s.          | < -17       | 158—159        | 24 |
| 0.869/20°            | i.            | s.          | s.          | liq.        | 158—159        | 25 |
| 0.865/21°            | i.            | s.          | s.          | liq.        | 161—162        | 26 |
| 0.725/0°             |               |             |             |             | 10.8           | 27 |
| 0.982/15°            | m.            |             |             | liq.        | 212—213        | 28 |
| 0.8125/13°           |               |             |             | - 85.9      | 79.6           | 29 |
|                      | h.s.s.        | s.s.        | s.          | 73—74       | subl.          | 30 |
| 0.837/20°            |               |             |             |             | 67             | 31 |
| 1.032/1°             | i.            | v.s.        | v.s.        |             | 161—162        | 32 |
| 1.0184/10°           |               |             |             |             | 251—262        | 33 |
|                      |               |             |             | - 14        | 251            | 34 |
|                      |               |             |             |             | 292—323/745mm. | 35 |
|                      |               |             |             | 193         | 315—316        | 36 |
| 1.0746/0°            |               |             |             | 5.5         | 272            | 37 |
|                      |               |             |             | 37          | 274—275        | 38 |
| 1.1123/15.5°         | i.            |             |             | - 112       | 86.3/728       | 39 |

| Name.                   | Formula.                     | Formula Weight. | Empirical Formula. |
|-------------------------|------------------------------|-----------------|--------------------|
| 1 Ethyl nitrite         | $C_2H_5.NO_2$                | 75.06           | $C_2H_5O_2N$       |
| 2 — nitrolic acid       | $CH_3.C(NO_2):NOH$           | 104.06          | $C_2H_4O_3N_2$     |
| 3 — ortho carbonate     | $C(OC_2H_5)_2$               | 192.21          | $C_2H_4O_3$        |
| 4 — phenol, <i>o</i>    | $C_6H_5.OH$                  | 122.12          | $C_6H_5O$          |
| 5 —, <i>p</i>           | " "                          | 122.12          | "                  |
| 6 — phenyl acetylene    | $C_6H_5.C : C.C_2H_5$        | 130.13          | $C_{10}H_{10}$     |
| 7 — carbamate, see      | Phenyl urethane              |                 |                    |
| 8 — carbinol            | $C_6H_5.CHOH.C_2H_5$         | 136.14          | $C_9H_{12}O$       |
| 9 — hydrazine, $\alpha$ | $C_6H_5.N(C_2H_5)_2.NH_2$    | 136.16          | $C_8H_{12}N_2$     |
| 10 —, $\beta$           | $C_6H_5.NH.NH.C_2H_5$        | 136.16          | "                  |
| 11 — ketone             | $C_6H_5.CO.C_2H_5$           | 134.13          | $C_9H_{10}O$       |
| 12 — sulphone           | $C_6H_5.SO_2.C_2H_5$         | 170.18          | $C_8H_{10}O_2S$    |
| 13 — urea               | $(C_2H_5)_2HN.CO.NH(C_6H_5)$ | 164.16          | $C_9H_{12}ON_2$    |
| 14 — phosphine          | $(C_2H_5)_2HP$               | 62.11           | $C_4H_7P$          |
| 15 — propyl carbinol    | $C_2H_5.CH_2.CHOH.C_2H_5$    | 102.14          | $C_6H_{14}O$       |
| 16 — ether              | $C_2H_5.O.C_2H_5$            | 88.12           | $C_4H_{10}O$       |
| 17 — ketone             | $C_2H_5.CO.C_2H_5$           | 100.13          | $C_5H_{12}O$       |
| 18 — pyridine, $\alpha$ | $C_5H_5N.C_2H_5$             | 107.12          | $C_7H_9N$          |
| 19 — silicate           | $Si(C_2H_5O)_2$              | 208.30          | $C_4H_{10}OSi$     |
| 20 — sulphate           | $(C_2H_5O)_2SO_2$            | 154.16          | $C_4H_{10}O_4S$    |
| 21 — sulphide           | $(C_2H_5)_2S$                | 90.16           | $C_4H_{10}S$       |
| 22 — sulphinic acid     | $C_2H_5.SO_2H$               | 94.12           | $C_2H_6O_2S$       |
| 23 — sulphite           | $(C_2H_5O)_2SO$              | 138.16          | $C_4H_{10}O_3S$    |
| 24 — sulphochloride     | $C_2H_5.SO_2Cl$              | 128.57          | $C_2H_5O_2SCl$     |
| 25 — sulphone           | $(C_2H_5)_2SO$               | 122.16          | $C_4H_{10}O_2S$    |
| 26 — sulphonic acid     | $C_2H_5.SO_2.OH$             | 110.12          | $C_2H_6O_3S$       |
| 27 — sulphoxide         | $(C_2H_5)_2SO$               | 106.16          | $C_4H_{10}OS$      |
| 28 — sulphuric acid     | $C_2H_5.HSO_4$               | 126.12          | $C_2H_5O_4S$       |
| 29 — thiocyanate        | $C_2H_5.SON^4$               | 87.11           | $C_2H_5NS$         |
| 30 —, <i>iso</i> .      | $C_2H_5.NOS$                 | 87.11           | "                  |
| 31 — toluene, see       | Ethyl methyl benzene         |                 |                    |
| 32 — vinyl ether        | $C_2H_5.O.C_2H_3$            | 72.08           | $C_4H_6O$          |
| 33 — xylene, 1:3:5      | $C_6H_3.C_2H_5:(OH)_2$       | 134.16          | $C_{10}H_{14}$     |
| 34 —, 1:3:4             | " "                          | 134.16          | "                  |
| 35 Ethylene             | $CH_2:CH_2$                  | 28.04           | $C_2H_4$           |
| 36 — bromide            | $C_2H_4Br_2$                 | 187.88          | $C_2H_4Br_2$       |
| 37 — chlorhydrin        | $CH_2Cl.CH_2OH$              | 80.50           | $C_2H_5OCl$        |
| 38 — chloride           | $C_2H_4Cl_2$                 | 98.96           | $C_2H_4Cl_2$       |
| 39 — cyanhydrin         | $CH_2OH.CH_2CN$              | 71.07           | $C_3H_5ON$         |

| Density<br>H <sub>2</sub> O=1. | Solubility in— |          |             | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|----------------|----------|-------------|-------------|-------------|----|
|                                | Water.         | Alcohol. | Ether.      |             |             |    |
| 0.9/15.5°                      | i.             | m.       |             | liq.        | 16.4        | 1  |
|                                | s.             |          | s.          | 88          |             | 2  |
| 0.9197/18.5°                   |                |          |             | liq.        | 158—159     | 3  |
| 1.0371/0°                      |                |          |             | < -18       | 198—199/720 | 4  |
|                                | i.             | s.       | s.          | 46          | 218.5—219   | 5  |
| 0.923/21°                      |                |          |             |             | 201—203     | 6  |
|                                |                |          |             |             |             | 7  |
| 0.99/15°                       |                | s.       | s.          | liq.        | 210—211/750 | 8  |
| 1.018/15°                      |                |          |             | liq.        | 237         | 9  |
|                                | s.s.           | s        | s.          | liq.        | 237—240/750 | 10 |
| 1.0141/15°                     |                |          |             | 14.5        | 215/746     | 11 |
|                                | C.S.S.         | s.       | s.          | 42          | > 300       | 12 |
|                                |                | s.       |             | 99          |             | 13 |
| < H <sub>2</sub> O             |                |          |             | liq.        | 25          | 14 |
| 0.8188/20°                     |                | s.       |             |             | 135         | 15 |
| 0.7545/0°                      |                |          |             |             | 60          | 16 |
| 0.818/17.5°                    |                |          |             | liq.        | 123/763.4   | 17 |
| 0.9498/0°                      |                |          |             |             | 148—150     | 18 |
| 0.933                          | d.             |          |             |             | 165         | 19 |
| 1.1837/19°                     | i.             | h.d.     |             | - 24.5      | 134.5/12mm. | 20 |
| 0.8368/20°                     | i.             |          | s. alk.     | liq.        | 92/754mm.   | 21 |
|                                |                |          |             |             |             | 22 |
| 1.1063/0°                      |                | s.       |             |             | 66.5/26mm.  | 23 |
| 1.357/20°                      | d.             |          |             | 29          | 122 d.      | 24 |
|                                | 1:6.4          |          |             | 73—74       | 248         | 25 |
|                                | del., v.s.     | s.       | s. alk.     |             |             | 26 |
|                                | s.             |          |             | 4—6         | 88—89/15mm. | 27 |
| 1.316/16°                      |                |          | s. alk      | liq.        | d.          | 28 |
| 0.9953/23.4°                   | i.             | m.       | m.          |             | 141—142     | 29 |
| 1.019/0°                       | i.             | s.       | s.          | - 5.9       | 132—133     | 30 |
|                                |                |          |             |             | /753mm      | 31 |
| 0.7625/14.5°                   | s.s.           | s        |             |             | 35.5        | 32 |
| 0.861/20°                      | i.             |          | s.          | liq.        | 185         | 33 |
| 0.8783/20°                     |                |          |             | liq.        | 183—184     | 34 |
|                                | 1:8 vol.       | 2:1      | 2:1         | - 169.5     | - 103       | 35 |
| 2.1823/20°                     | i.             | s.       |             | 9.95        | 131.6/769.8 | 36 |
| 1.24/8°                        | s.             | s.       | s.          |             | 128         | 37 |
| 1.2521/20°                     | i.             | s.       |             | - 40        | 57.5/751mm. | 38 |
| 1.059/0°                       | m.             | m.       | 2.3:100/15° | liq.        | 221/753mm.  | 39 |

| Name.                  | Formula.  | Formula Empirical<br>Weight. Formula. |
|------------------------|---|---------------------------------------|
| 1 Ethylene cyanide     | $C_2H_4(CN)_2$  | 80.07 $C_4H_4N_4$                     |
| 2 —diamine             | $C_2H_4(NH_2)_2 \cdot H_2O$   | 78.11 $C_2H_8N_2$                     |
| 3 —diphenyl ether      | $(C_6H_5O)_2$   | 214.18 $C_{12}H_{10}O_2$              |
| 4 —disulphonic acid    | $C_2H_4(SO_3H)_2$   | 190.18 $C_2H_6O_6S_2$                 |
| 5 —ethylidene oxide    | $CH_3 \cdot CH \begin{matrix} \diagup OCH_2 \\ \diagdown OCH_2 \end{matrix}$                    | 88.08 $C_4H_8O_2$                     |
| 6 —iodide              | $C_2H_4I_2$   | 281.88 $C_2H_4I_2$                    |
| 7 —mercaptan           | $C_2H_4(SH)_2$  | 94.18 $C_2H_6S_2$                     |
| 8 —nitrate             | $C_2H_4(NO_3)_2$  | 152.06 $C_2H_4O_6N_2$                 |
| 9 —nitrite             | $C_2H_4(NO_2)_2$  | 120.06 $C_2H_4O_4N_2$                 |
| 10 —oxide              | $C_2H_4O$   | 44.04 $C_2H_4O$                       |
| 11 — — sulphone        | $(C_6H_5SO_2)_2$  | 310.30 $C_{12}H_{14}O_4S_2$           |
| 12 —sulphide           | $(C_6H_5S)_2$   | 120.20 $C_6H_8S_2$                    |
| 13 —thiocyanate        | $C_2H_4(SCN)_2$   | 144.19 $C_2H_4N_2S_2$                 |
| 14 —urea               | $CO:(NH \cdot CH_2)_2$  | 86.08 $C_3H_6ON_2$                    |
| 15 Ethylidene acetone  | $CH_3 \cdot CO \cdot CH:CH \cdot CH_3$  | 84.09 $C_5H_8O$                       |
| 16 —cyanhydrin         | $CH_3 \cdot CH(OH)CN$   | 71.07 $C_3H_5ON$                      |
| 17 —urea               | $CO:(NH)_2 \cdot CH \cdot CH_3$   | 86.08 $C_3H_5ON_2$                    |
| 18 —urethane           | $C_2H_4(NH \cdot COO \cdot C_2H_5)_2$   | 204.19 $C_8H_{16}O_4N_2$              |
| 19 Eugenol acid        | $C_6H_2(OH)(OCH_3)(COOH)$   | 208.15 $C_{11}H_{12}O_4$              |
| 20 Eugenol, 4:3:1      | $C_6H_3(OH)(OCH_3)CH_2 \cdot CH:CH_2$   | 164.15 $C_{10}H_{12}O_2$              |
| 21 Eupittonic acid     | $C_{19}H_{18}O_5(OCH_3)_6$  | 479.33 $C_{25}H_{26}O_9$              |
| 22 Euxanthic acid      | $C_{13}H_{10}O_5 \cdot 3H_2O$   | 246.15 $C_{13}H_{10}O_5$              |
| 23 Euxanthinic acid    | $C_{19}H_{18}O_{10} \cdot 3H_2O$  | 460.29 $C_{19}H_{18}O_{10}$           |
| 24 Euxanthone          | $OH \cdot C_6H_3 \begin{matrix} \diagup CO \\ \diagdown O \end{matrix} C_6H_3 \cdot OH$         | 228.13 $C_{12}H_8O_4$                 |
| 25 Evernic acid        | $C_{17}H_{16}O_7$   | 332.21 $C_{17}H_{16}O_7$              |
| 26 Everniine           | $C_{17}H_{14}O_7$   | 198.14 $C_6H_{14}O_7$                 |
| 27 Everninic acid      | $C_8H_7(OH)_2COOH \cdot H_2O$   | 200.15 $C_9H_{10}O_4$                 |
| 28 Fenchene            | $C_{10}H_{16}$  | 136.18 $C_{10}H_{16}$                 |
| 29 Fenchone            | $C_{10}H_{16}O$   | 152.18 $C_{10}H_{16}O$                |
| 30 Ferulic acid, 3:4:1 | $C_6H_3(OCH_3)OH \cdot C_2H_2 \cdot COOH$   | 194.13 $C_{10}H_{10}O_4$              |
| 31 Fisetin             | $OH \begin{matrix} \diagup O-C_6H_3(OH)_2 \\ \diagdown CO \cdot C(OH) \cdot 4H_2O \end{matrix}$ | 358.22 $C_{15}H_{10}O_6$              |



| Density<br>H <sub>2</sub> O=1. | Solubility in |               |                      | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|---------------|---------------|----------------------|-------------|-------------|----|
|                                | Water.        | Alcohol.      | Ether.               |             |             |    |
| 1.23/45°                       | s.            | s.            | s.s.                 | 54.5        | 158—160/20  | 1  |
| 0.970/15°                      | s.            |               | v.s.s.               | 10          | 116         | 2  |
|                                | i.            | h.s.          | s                    | 98.5        |             | 3  |
|                                | del.          | s.            |                      | 94          |             | 4  |
| 1.002                          | 1:1.5         |               |                      |             | 82.5        | 5  |
| 2.07                           |               | s.            |                      | 81—82       | d.          | 6  |
| 1.123/23°                      | s. alk.       | s.            |                      | liq.        | 146         | 7  |
| 1.472                          |               | s.            |                      | liq.        | d.          | 8  |
| 1.2156/0°                      | i.            | s.            | s.                   | 37.5        | subl.       | 9  |
| 0.896/0°                       | v.s.          | v.s.          | v.s.                 | liq.        | 13.5/746mm. | 10 |
|                                | i.            | h.s.s.        | s. acetic.           | 179.5—180   |             | 11 |
|                                | i.            | s.            | s.                   | 110         | subl. 200   | 12 |
|                                | h.s.          | s.            |                      | 90          | d.          | 13 |
|                                |               |               | s. CHCl <sub>3</sub> | 131         |             | 14 |
| 0.861/15°                      | s.            |               |                      |             | 122—123/741 | 15 |
|                                | s.            | s.            | s.                   |             | 182—184 d.  | 16 |
|                                | v.s.s.        | s.s.          | v.s.s.               | 154         | d. 100      | 17 |
|                                | h.s.          | s.            | s.                   | 125—126     | d.          | 18 |
|                                | c.s.s.        | s.            | s                    | 124         |             | 19 |
| 1.0703/14°                     | v.s.s.        | s.            | s.                   | liq.        | 247.5       | 20 |
|                                | s. alk. to B  | h.s.s. (abs.) | s. acetic            | d. 200      |             | 21 |
|                                | h.s.          | s. (abs.)     | s. alk.              | 200—202     |             | 22 |
|                                | h.s.          | h.s.          | v.s.                 | d. 160      |             | 23 |
|                                | s. alk.       | h.s.          | s.s.                 | 237—238     |             | 24 |
|                                | h.s.s.        | s.            | s.                   | 164—170     |             | 25 |
|                                | v.s.          | i.            |                      |             |             | 26 |
|                                | h.s.          | s.            | s.                   | 157         |             | 27 |
| 0.864/20°                      |               |               |                      |             | 158—160     | 28 |
| 0.9465/19°                     |               | s.            |                      | 5—6         | 194—195     | 29 |
|                                | h.s.          | c.s.          | s.s.                 | 170         | d.          | 30 |
|                                |               | s.            |                      | 330 d.      |             | 31 |

| Name.                                  | Formula.  | Formula Empirical<br>Weight. Formula. |
|--|---|---------------------------------------|
| 1 Flavaniline                          | $C_{16}H_{12}N.NH_2$  | 234.21 $C_{16}H_{14}N_2$              |
| 2 Flaveanhydride                       | $CN.CS.NH_2$  | 88.11 $C_2H_2N_2S$                    |
| 3 Flavone                              | $C_6H_4 \begin{cases} O-C_6H_5 \\ \parallel \\ CO.CH \end{cases}$ | 222.16 $C_{15}H_{10}O_2$              |
| 4 Flavopurpurin, see                   | Trihydroxy anthraquinone  |                                       |
| 5 Fluorane                             | $C_6H_4.C:(C_6H_4)_2:O$   | 300.20 $C_{20}H_{12}O_3$              |
|  | $CO-O$  |                                       |
| 6 Fluoranthene                         | $C_{15}H_{10}$  | 190.16 $C_{15}H_{10}$                 |
| 7 Fluor benzene                        | $C_6H_5F$   | 96.07 $C_6H_5F$                       |
| 8 — benzoic acid                       | $C_6H_5.F.CO.OH$  | 140.08 $C_7H_5O_2F$                   |
| 9 Fluorene                             | $(C_6H_4)_2:CH_2$   | 166.15 $C_{13}H_{10}$                 |
| 10 — alcohol                           | $(C_6H_4)_2:CHOH$   | 182.15 $C_{13}H_{10}O$                |
| 11 Fluorenone, di-<br>phenylene ketone | $(C_6H_4)_2:CO$   | 180.12 $C_{13}H_8O$                   |
| 12 Fluorescein                         | $C_{20}H_{12}O_5$   | 332.10 $C_{20}H_{12}O_5$              |
| 13 Formaldehyde                        | $H.CHO$   | 30.02 $CH_2O$                         |
| 14 Formaldoxime                        | $H.CH:NOH$  | 45.04 $CH_2ON$                        |
| 15 Formamide                           | $H.CO.NH_2$   | 45.04 $CH_3ON$                        |
| 16 — oxime                             | $CH(NH_2):NOH$  | 60.06 $CH_3ON_2$                      |
| 17 Formanilide                         | $C_6H_5.NH.CHO$   | 121.10 $C_7H_7ON$                     |
| 18 Formic acid                         | $H.CO.OH$   | 46.02 $CH_2O_2$                       |
| 19 Formate, calcium                    | $(H.COO)_2Ca$   | 130.10 $C_2H_2O_4Ca$                  |
| 20 —, copper                           | $(H.COO)_2Cu.(4H_2O)$   | 153.60 $C_2H_2O_4Cu$                  |
| 21 —, lead                             | $(H.COO)_2Pb$   | 297.23 $C_2H_2O_4Pb$                  |
| 22 —, sodium                           | $H.COONa$   | 68.01 $CH_2O_2Na$                     |
| 23 —, allyl                            | $H.COO.C_3H_5$  | 86.07 $C_4H_6O_2$                     |
| 24 —, <i>iso</i> amyl                  | $H.COO.C_5H_{11}$   | 116.13 $C_6H_{12}O_2$                 |
| 25 —, ethyl                            | $H.COO.C_2H_5$  | 74.06 $C_3H_6O_2$                     |
| 26 —, methyl                           | $H.COO.CH_3$  | 60.04 $C_2H_4O_2$                     |
| 27 Formyl diphenyl-<br>amine           | $CHO.N(C_6H_5)_2$   | 197.16 $C_{13}H_{11}ON$               |
| 28 — hydrazine                         | $HCO.NH.NH_2$   | 60.06 $CH_3ON$                        |
| 29 Frangulin                           | $C_{21}H_{20}O_9$   | 416.26 $C_{21}H_{20}O_9$              |
| 30 Fraxine                             | $C_{16}H_{18}O_{10}$  | 370.22 $C_{16}H_{18}O_{10}$           |
| 31 Fulminate, mercuric                 | $(CNO)_2Hg.2H_2O$   | 293.65 $C_2O_2N_2Hg$                  |
| 32 —, silver                           | $CNOAg$   | 149.90 $CNOAg$                        |
| 33 Fulminic acid                       | $C_3H_3N_3O_3$  | 129.07 $C_3H_3O_3N_3$                 |
| 34 Fumaric acid                        | $C_2H_2(COOH)_2$  | 116.05 $C_4H_4O_4$                    |

| Density<br>H <sub>2</sub> O=1. | Solubility in |          |                                  | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|---------------|----------|----------------------------------|-------------|-------------|----|
|                                | Water.        | Alcohol. | Ether.                           |             |             |    |
|                                | v.s.s.        | s.       | s. C <sub>6</sub> H <sub>6</sub> | 97          |             | 1  |
|                                | s.            | s.       | v.s.                             | d. 87—90    |             | 2  |
|                                | i.            | s.       | s.                               | 97          |             | 3  |
|                                |               | s.       |                                  | 182         |             | 4  |
|                                |               |          |                                  |             |             | 5  |
| 1.0236/20°                     | s. acetic     | h.s.     | s., s. CS <sub>2</sub>           | 109—110     | 250—251/60  | 6  |
|                                | h.s.          | s.       | s.                               | 182         | 84.5        | 7  |
|                                |               | h.s.     | s.                               | 115         | 294—295     | 8  |
|                                |               | s.       | s.                               | 153         |             | 9  |
|                                | i.            | v.s.     | v.s.                             |             | 341.5       | 10 |
|                                |               |          |                                  |             |             | 11 |
|                                | h.s.s.        | s.       | s.                               | d.          |             | 12 |
|                                | s.            | s.       |                                  | - 92        | - 21        | 13 |
|                                | s.            |          |                                  |             | 84—85       | 14 |
| 1.1337/14.1°                   | s.            | s.       | s.                               | - 1         | 85—95/0.5   | 15 |
|                                | s.            | s.       | s.                               | 114—115     | d.          | 16 |
|                                | s.            | s.       | s.                               | 50          | 271         | 17 |
| 1.2256/15°                     | m.            | s.       | s.                               | 8.5         | 100.6       | 18 |
| 2.015                          | s.            | i.       |                                  |             |             | 19 |
| 1.831                          | s.            |          |                                  |             |             | 20 |
| 4.56                           | 1:63/16°      | i.       |                                  |             |             | 21 |
| 1.919                          | v.s.          | s.       |                                  |             |             | 22 |
| 0.93/17.5°                     |               | s.       |                                  | liq.        | 81—83       | 23 |
| 0.894/0°                       | 1:325/22°     |          |                                  | liq.        | 130.4       | 24 |
| 0.9445/0°                      | 11:10         | s.       | s.                               | - 78.9      | 54.4        | 25 |
| 0.986/11°                      |               |          |                                  | - 100.4     | 32.2        | 26 |
|                                | s.            |          |                                  | 73—74       | 210—220     | 27 |
|                                |               |          |                                  |             | in vac.     |    |
|                                |               |          |                                  | 54          |             | 28 |
|                                | i.            | h.s.     | h.s.                             | 286         |             | 29 |
|                                | h.s.          | h.s.     |                                  | 190         |             | 30 |
| 4.42 (an.)                     | h.s.          | s.       |                                  | expl.       |             | 31 |
|                                | 1:36, h.      |          |                                  | expl.       |             | 32 |
|                                | s.            | s.       | s.                               | 136—139     |             | 33 |
| 1.625                          | 1:150/16.5°   | s.       | s.                               | 286—287     | 200 subl    | 34 |

| Name.                              | Formula.  | Formula Weight. | Empirical Formula.                               |
|------------------------------------|---|-----------------|--|
| 1 Furane                           | $\text{CH:CH} \begin{array}{c}   \\ \text{O} \end{array}$                         | 68.05           | $\text{C}_4\text{H}_4\text{O}$                   |
| 2 Furfural                         | $\text{CH:CH} \begin{array}{c}   \\ \text{C}_4\text{H}_3\text{O.CHO} \end{array}$ | 96.06           | $\text{C}_5\text{H}_4\text{O}_2$                 |
| 3 Furfur alcohol                   | $\text{C}_4\text{H}_3\text{O.CH}_2\text{OH}$                                      | 98.07           | $\text{C}_5\text{H}_6\text{O}_2$                 |
| 4 — amide                          | $(\text{C}_4\text{H}_3\text{O})_3\text{N}_2$                                      | 268.19          | $\text{C}_{15}\text{H}_{12}\text{O}_3\text{N}_2$ |
| 5 Furfurin                         | $\text{C}_4\text{H}_4\text{N}_2\text{O}$  | 268.19          | "  |
| 6 Furyl amine                      | $\text{C}_4\text{H}_3\text{O.CH}_2\text{NH}_2$                                    | 97.09           | $\text{C}_5\text{H}_7\text{ON}$                  |
| 7 Galactose, l                     | $\text{C}_6\text{H}_{12}\text{O}_6$   | 180.13          | $\text{C}_6\text{H}_{12}\text{O}_6$              |
| 8 —, d                             | "   | 180.13          | "  |
| 9 Gallein                          | $\text{C}_{20}\text{H}_{10}\text{O}_7$  | 362.18          | $\text{C}_{20}\text{H}_{10}\text{O}_7$           |
| 10 Gallic acid, 3:4:5:1            | $\text{C}_6\text{H}_2(\text{OH})_3\text{COCH}_2\text{H}_2\text{O}$                | 188.10          | $\text{C}_7\text{H}_6\text{O}_5$                 |
| 11 Gallin                          | $\text{C}_{20}\text{H}_{14}\text{O}_7$  | 366.21          | $\text{C}_{20}\text{H}_{14}\text{O}_7$           |
| 12 Gaultherin                      | $\text{C}_6\text{H}_{11}\text{O}_5.\text{O.C}_6\text{H}_4.\text{COOCH}_3$         | 314.21          | $\text{C}_{14}\text{H}_{18}\text{O}_8$           |
| 13 Gaultherinic acid               | $\text{C}_{36}\text{H}_{54}\text{O}_6$  | 582.61          | $\text{C}_{36}\text{H}_{54}\text{O}_6$           |
| 14 Gentisin                        | $\text{C}_{14}\text{H}_{10}\text{O}_5$  | 258.15          | $\text{C}_{14}\text{H}_{10}\text{O}_5$           |
| 15 Geraniol                        | $\text{C}_{10}\text{H}_{18}\text{O}$  | 154.19          | $\text{C}_{10}\text{H}_{18}\text{O}$             |
| 16 Gluconic acid, d                | $\text{C}_6\text{H}_{12}(\text{OH})_5\text{COOH}$                                 | 196.13          | $\text{C}_6\text{H}_{12}\text{O}_7$              |
| 17 Glucose                         | $\text{C}_6\text{H}_{12}\text{O}_6$   | 198.15          | $\text{C}_6\text{H}_{12}\text{O}_6$              |
| 18 —, anhydr.                      | $\text{C}_6\text{H}_{10}\text{O}_5$   | 180.13          | "  |
| 19 — phenylhydrazone, $\alpha$     | $\text{C}_6\text{H}_{12}\text{O}_5(\text{N}_2\text{H.C}_6\text{H}_5)$             | 270.22          | $\text{C}_{12}\text{H}_{18}\text{O}_5\text{N}_2$ |
| 20 Glucosamine, d                  | $\text{C}_6\text{H}_{13}\text{O}_5\text{N}$                                       | 179.14          | $\text{C}_6\text{H}_{13}\text{O}_5\text{N}$      |
| 21 Glucosazone, $\alpha$           | $\text{C}_6\text{H}_{10}\text{O}_4(\text{N}_2\text{H.C}_6\text{H}_5)_2$           | 358.31          | $\text{C}_{18}\text{H}_{22}\text{O}_4\text{N}_2$ |
| 22 Glucosoxime, $\alpha$           | $\text{C}_6\text{H}_{12}\text{O}_5:\text{NOH}$                                    | 195.14          | $\text{C}_6\text{H}_{13}\text{O}_5\text{N}$      |
| 23 Glucosone                       | $\text{C}_4\text{H}_9\text{O}_4.\text{CO.CHO}$                                    | 178.11          | $\text{C}_6\text{H}_{10}\text{O}_6$              |
| 24 Glucuronic acid                 | $\text{CHO}(\text{CHOH})_4.\text{COOH}$   | 194.11          | $\text{C}_6\text{H}_{10}\text{O}_7$              |
| 25 Glutamine                       | $\text{C}_3\text{H}_5(\text{NH}_2)(\text{CONH}_2)\text{COOH}$                     | 146.13          | $\text{C}_5\text{H}_{10}\text{O}_3\text{N}_2$    |
| 26 Glutaminic acid, i              | $\text{C}_3\text{H}_5(\text{NH}_2)(\text{COOH})_2$                                | 147.11          | $\text{C}_5\text{H}_9\text{O}_4\text{N}$         |
| 27 Glutaric acid                   | $\text{HOOC}(\text{CH}_2)_3.\text{COOH}$  | 132.09          | $\text{C}_5\text{H}_8\text{O}_4$                 |
| 28 Glyceric acid, $\alpha$         | $\text{CH}_2\text{OH}.\text{CHOH}.\text{COOH}$                                    | 106.06          | $\text{C}_3\text{H}_6\text{O}_4$                 |
| 29 Glycerol                        | $\text{C}_3\text{H}_5(\text{OH})_3$   | 92.08           | $\text{C}_3\text{H}_8\text{O}_3$                 |
| 30 — aldehyde                      | $\text{CH}_2\text{OH}.\text{CHOH}.\text{CHO}$                                     | 90.06           | $\text{C}_3\text{H}_6\text{O}_3$                 |
| 31 — diethyl ether, $\alpha\alpha$ | $(\text{CH}_2\text{O.C}_2\text{H}_5)_2:\text{CHOH}$                               | 148.16          | $\text{C}_7\text{H}_{16}\text{O}_3$              |
| 32 — monoethyl ether, $\alpha$     | $(\text{CH}_2\text{O.C}_2\text{H}_5).\text{CHOH}.\text{CH}_2\text{OH}$            | 120.12          | $\text{C}_5\text{H}_{12}\text{O}_3$              |
| 33 — mercaptan                     | $\text{C}_3\text{H}_5(\text{OH})(\text{SH})_2$                                    | 124.20          | $\text{C}_3\text{H}_8\text{OS}_2$                |
| dithioglycerol                     |   |                 |  |
| 34 —, monothioglycerol             | $\text{C}_3\text{H}_5(\text{OH})_2(\text{SH})$                                    | 108.14          | $\text{C}_3\text{H}_8\text{O}_2\text{S}$         |
| 35 —, trithioglycerol              | $\text{C}_3\text{H}_5(\text{SH})_3$   | 140.26          | $\text{C}_3\text{H}_8\text{S}_3$                 |
| 36 — phosphoric acid               | $\text{C}_3\text{H}_5(\text{OH})_2\text{OP}(\text{OH})_2$                         | 156.13          | $\text{C}_3\text{H}_9\text{O}_5\text{P}$         |

| Density<br>H <sub>2</sub> O=1. | Solubility in |            |               | M.P.<br>°C.         | B.P.<br>°C.          |    |
|--------------------------------|---------------|------------|---------------|---------------------|----------------------|----|
|                                | Water.        | Alcohol.   | Ether.        |                     |                      |    |
| .9086/21.6                     | i.            | s.         | s.            | liq.                | 31.6                 | 1  |
| .1636/13.5°                    | 1:11/13°      | s.         | s.            | -36.5               | 158.5—159            | 2  |
| .1355/20°                      | s.            | s.         | s.            | 200 subl.           | 166—170/725          | 3  |
|                                | c.i.          | s.         | s.            | 117                 | d. 250               | 4  |
|                                | 1:135/100°    | v.s.       | v.s.          | 116                 |                      | 5  |
| <H <sub>2</sub> O              | m.            |            |               | liq.                | 145/754mm.           | 6  |
|                                | s.            | v.s.s.     |               | 162—163             |                      | 7  |
|                                | s.            |            |               | 168                 |                      | 8  |
|                                | h.s.s.        | v.s.       | s.s., s. alk. | d.                  |                      | 9  |
| .694/4°                        | 1:3/100°      | 28:100/15° | 2.5:100/15°   |                     | 253 d.               | 10 |
|                                | s.            | s.         | s.            |                     |                      | 11 |
|                                | s.            | s.         | i.            | 251—252             | subl.                | 12 |
|                                | s.s.          | s.         |               | 195                 |                      | 13 |
|                                | v.s.s.        | v.s.s.     | v.s.s.        | 267                 | 300—400<br>subl & d. | 14 |
| .8965/0°                       | i.            | m.         | m.            |                     | 230                  | 15 |
|                                | v.s.          | i.         |               |                     |                      | 16 |
| .54—1.57                       | 98:100/18°    | s.         |               | 82                  |                      | 17 |
|                                | s.            | v.s.       |               | 146                 |                      | 18 |
|                                | s.            | h.s.       | i             | 115, $\beta$ 144    |                      | 19 |
|                                | s.s.          | s.         | i.            | 110 d.              |                      | 20 |
|                                | i.            | h.s.       |               | 145, $\beta$ 204 d. |                      | 21 |
|                                | v.s.          | s.s.       | i.            | 136—137             |                      | 22 |
|                                | s.            | s.         | i.            |                     |                      | 23 |
|                                |               | s.         |               | aq. 175             |                      | 24 |
|                                | 1:25/16°      | i.         | i.            |                     |                      | 25 |
| .538                           | 1:100/16°     | s.s.       | i.            | 198                 |                      | 26 |
| .1919/106.4°                   | 1:1.2/14°     | v.s.       | v.s.          | 97.5                | 200/20mm.            | 27 |
|                                | l.            | m.         | i.            | liq.                |                      | 28 |
| .2604/20°                      | m.            | s.         | i.            | 20                  | 290                  | 29 |
|                                | s.s.          | v.s.s.     | v.s.s.        | 132                 |                      | 30 |
| .920/21°                       |               |            |               |                     | 191                  | 31 |
|                                |               |            |               |                     | 225—230              | 32 |
| 34                             | i.            | s.         | i.            | liq.                |                      | 33 |
|                                | s.s.          | s.         | i.            | liq.                |                      | 34 |
| 29                             | i.            | s.         | i.            | liq.                |                      | 35 |
| 39                             | s., h.d.      | s.         |               | d.                  |                      | 36 |

| Name.                          | Formula.  | Formula Weight. | Empirical Formula.     |
|--------------------------------|---|-----------------|------------------------|
| 1 Glyceryl chloride            | $C_3H_5Cl_3$  | 147.44          | $C_3H_5Cl_3$           |
| 2 — ether                      | $(C_3H_5)_2O_3$   | 130.11          | $C_6H_{10}O_3$         |
| 3 Glycide                      | $O \begin{array}{l} \diagup CH_2CH_2OH \\   \\ CH_2 \end{array}$  | 74.06           | $C_3H_6O_2$            |
| 4 Glycine, see                 | Amino acetic acid   |                 |                        |
| 5 Glycocycamine                | $C(NH)(NH_2)NH.CH_2.COOH$   | 117.09          | $C_3H_7O_2N_3$         |
| 6 Glycol                       | $C_2H_4(OH)_2$  | 62.06           | $C_2H_6O_2$            |
| 7 — acetate                    | $C_2H_4(OH)_2OOC.CH_3$  | 104.08          | $C_4H_8O_3$            |
| 8 — amide                      | $CH_2OH.CONH_2$   | 75.06           | $C_2H_5O_2N$           |
| 9 — di-acetate                 | $C_2H_4(OOC.CH_3)_2$  | 146.11          | $C_4H_6O_4$            |
| 10 Glycollic acid              | $CH_2OH.COOH$   | 76.04           | $C_2H_4O_3$            |
| 11 Glycollide                  | $\left( \begin{array}{c} CH_2 \\   \\ CO \end{array} \right)_x$   | (58.03)         |                        |
| 12 Glycol thiourea             | $C_2H_4N_2SO$   | 116.13          | $C_2H_4ON_2S$          |
| 13 Glyoxal                     | $CHO.CHO$   | 58.03           | $C_2H_2O_2$            |
| 14 Glyoxaline                  | $CH \begin{array}{l} \diagup NH.CH \\ \diagdown N=CH \end{array}$ | 68.07           | $C_3H_4N_2$            |
| 15 Glyoxime                    | $(CH:NOH).(CH:NOH)$   | 88.06           | $C_2H_4O_2N_2$         |
| 16 Glyoxylic acid              | $CHO.COOH.H_2O$   | 92.05           | $C_2H_4O_3$            |
| 17 Guaiacol, 1 : 2             | $C_6H_4(OH)OCH_3$   | 124.10          | $C_7H_8O_2$            |
| 18 Guaiacol carbonate          | $C_{15}H_{14}O_5$   | 274.19          | $C_7H_8O_5$            |
| 19 Guanidine,<br>(carbamidine) | $NH:C:(NH_2)_2$   | 59.08           | $CH_5N_3$              |
| 20 Guanine                     | $C_5H_5N_5O$  | 151.12          | $C_5H_5ON_5$           |
| 21 Hæmateïn                    | $C_{16}H_{12}O_6$   | 300.18          | $C_6H_{12}O_6$         |
| 22 Hæmatin                     | $Fe(C_{16}H_{16}N_2O_2)_2$  | 592.30          | $C_{32}H_{32}O_4N_4Fe$ |
| 23 Hæmatoxylin                 | $C_{16}H_9O(OH)_5.3H_2O$  | 356.24          | $C_{16}H_{14}O_6$      |
| 24 Helicin                     | $C_{13}H_{16}O_7.3H_2O$   | 297.71          | $C_{13}H_{16}O_7$      |
| 25 Heliotropin, see            | Piperonal   |                 |                        |
| 26 Hemimellitic acid, 1 : 2    | $3C_6H_3(COOH)_3.2H_2O$   | 246.12          | $C_9H_6O_6$            |
| 27 Hemipinic acid, 3 : 4 : 1   | $3C_6H_3(OCH_3)_2(COOH)_2.2H_2O$                                  | 262.16          | $C_{10}H_{10}O_6$      |
| 28 —, 4 : 5 : 1 : 2            | " "   | 226.13          | " "                    |
| 29 —, 5 : 6 : 1 : 2            | $C_6H_2(OCH_3)_2(COOH)_2$   | 226.13          | $C_{10}H_{10}O_6$      |
| 30 Heptamethylene, see         | Cyclo heptane   |                 |                        |

| Density<br>$H_2O=1$ . | Solubility in   |          |             | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------|-----------------|----------|-------------|-------------|-------------|----|
|                       | Water.          | Alcohol. | Ether.      |             |             |    |
| 1.417/15°             |                 |          |             | liq.        | 154—156     | 1  |
| 1.16/16°              | m.              | m.       | m.          | liq.        | 171—172     | 2  |
| 1.165/0°              | m.              | m.       | m.          |             | 162/751mm.  | 3  |
|                       |                 |          |             |             |             | 4  |
|                       | 1:227/<br>14.5° | i.       | i.          | - 11.2      |             | 5  |
| 1.1098/25°            | m.              | m.       | i.          | - 17.4      | 197/260mm.  | 6  |
| >H <sub>2</sub> O     | m.              | m.       |             | liq.        | 182         | 7  |
|                       | s.              | s.s.     |             | 117—118     |             | 8  |
| >H <sub>2</sub> O     | 1:7             | s.       | s.          | liq.        | 186—187     | 9  |
|                       | s.              | m        | m.          | 80          | d.          | 10 |
|                       | h.v.s.s         |          |             | 220         |             | 11 |
|                       | h.s.            | i.       | i.          | d. 200      |             | 12 |
|                       | v.s.            | v.s.     | s.          | 15          | 51          | 13 |
|                       | s.              | s.       | s.          | 88—89       | 255         | 14 |
|                       | h.s.            | s.       | s.          | 178         | subl.       | 15 |
|                       | s.              |          | vol. steam. | syrup.      |             | 16 |
| 1.1385/15°            | 1:60/15°        | s.       | s.          | 32          | 205         | 17 |
|                       |                 |          |             | 86          |             | 18 |
|                       | s.              |          |             |             |             | 19 |
|                       | i.              |          |             | d           |             | 20 |
|                       | s.s.            | s.s.     | s.s.        |             |             | 21 |
|                       | i.              | i.       | i.          |             |             | 22 |
|                       | h.s.            | s.       | s.          | 100—120     |             | 23 |
|                       | h.v.s.          | s.       | i.          | an. 175     |             | 24 |
|                       |                 |          |             |             |             | 25 |
|                       | 3.15:100/19°    |          | s           | 196 d.      |             | 26 |
|                       | c.s.s.          | s.       |             | 184—185 d   |             | 27 |
|                       |                 |          |             | 178         |             | 28 |
|                       |                 |          |             | 180         |             | 29 |
|                       |                 |          |             |             |             | 30 |

| Name.                               | Formula.   | Formula Weight. | Empirical Formula.                        |
|-------------------------------------|--|-----------------|---|
| 1 Heptane, 1 norm.                  | $\text{CH}_3(\text{CH}_2)_5\text{CH}_3$                                    | 100.16          | $\text{C}_7\text{H}_{16}$                 |
| 2 —, 2. ethyl <i>iso</i> amyl       | $\text{CH}_3(\text{CH}_2)_3\text{CH}:(\text{CH}_3)_2$                      | 100.16          | "   |
| 3 —, 3. triethyl methane            | $\text{CH}(\text{C}_2\text{H}_5)_3$  | 100.16          | "   |
| 4 —, 4. dimethyl diethyl methane    | $(\text{CH}_3)_2\text{C}:(\text{C}_2\text{H}_5)_2$                         | 100.16          | "   |
| 5 Heptine, cenanthine               | $\text{CH}_3(\text{CH}_2)_4\text{C}:\text{CH}$                             | 96.13           | $\text{C}_7\text{H}_{12}$                 |
| 6 Heptyl alcohol, 1 nor.            | $\text{C}_7\text{H}_{15}\text{OH}$   | 116.16          | $\text{C}_7\text{H}_{16}\text{O}$         |
| 7 —, 2. dipropyl carbinol           | $\text{CH}_3(\text{CH}_2)_2\text{CHOH}(\text{CH}_2)_2\text{CH}_3$          | 116.16          | "   |
| 8 —, 3. di-isopropyl carbinol       | $(\text{CH}_3)_2\text{CH}:\text{CHOH}:\text{CH}:(\text{CH}_3)_2$           | 116.16          | "   |
| 9 —, 4. triethyl carbinol           | $(\text{C}_2\text{H}_5)_3\text{C.OH}$                                      | 116.16          | "   |
| 10 —, 5. dimethyl isobutyl carbinol | $(\text{CH}_3)_2\text{C}:\text{COH}.\text{CH}_2.\text{CH}:(\text{CH}_3)_2$ | 116.16          | "   |
| 11 —, 6. pentamethyl ethol          | $(\text{CH}_3)_3\text{C.C}(\text{CH}_3)_2\text{OH}$                        | 116.16          | "   |
| 12 — aldehyde, cenanthol            | $\text{C}_6\text{H}_{13}\text{CHO}$  | 114.15          | $\text{C}_7\text{H}_{14}\text{O}$         |
| 13 Heptylene, norm.                 | $\text{C}_7\text{H}_{14}$  | 98.15           | $\text{C}_7\text{H}_{14}$                 |
| 14 Heptylic acid, norm.             | $\text{C}_6\text{H}_{13}\text{COOH}$                                       | 130.15          | $\text{C}_7\text{H}_{14}\text{O}_2$       |
| 15 —, iso                           | "  | 130.15          | "   |
| 16 Heptylate, ethyl                 | $\text{CH}_3(\text{CH}_2)_5\text{COOC}_2\text{H}_5$                        | 158.19          | $\text{C}_9\text{H}_{18}\text{O}_2$       |
| 17 Heptylic anhydride               | $(\text{C}_6\text{H}_{13}\text{CO})_2\text{O}$                             | 242.28          | $\text{C}_{14}\text{H}_{26}\text{O}_3$    |
| 18 Hesperidin                       | $\text{C}_{22}\text{H}_{26}\text{O}_{12}$                                  | 482.32          | $\text{C}_{22}\text{H}_{26}\text{O}_{12}$ |
| 19 Hexa chlor benzene               | $\text{C}_6\text{Cl}_6$  | 285.39          | $\text{C}_6\text{Cl}_6$                   |
| 20 — ethane                         | $\text{C}_2\text{Cl}_6$  | 236.77          | $\text{C}_2\text{Cl}_6$                   |
| 21 — decane, dioctyl                | $\text{C}_{16}\text{H}_{34}$   | 226.35          | $\text{C}_{16}\text{H}_{34}$              |
| 22 — ethyl benzene                  | $\text{C}_6(\text{C}_2\text{H}_5)_6$                                       | 246.33          | $\text{C}_{18}\text{H}_{30}$              |
| 23 — hydro benzene, see             | Cyclo hexane   |                 |   |
| 24 — benzoic acid                   | $\text{C}_6\text{H}_5(\text{H}_6)\text{COOH}$                              | 128.13          | $\text{C}_7\text{H}_{12}\text{O}_2$       |
| 25 — cumene                         | $\text{C}_9\text{H}_{12}(\text{H}_6)$                                      | 126.19          | $\text{C}_9\text{H}_{18}$                 |
| 26 — cymene                         | $\text{CH}_3\text{C}_6\text{H}_4(\text{H}_6).\text{C}_3\text{H}_7$         | 140.21          | $\text{C}_{10}\text{H}_{20}$              |
| 27 — phenol, see                    | Cyclo hexanol  |                 |   |
| 28 — salicylic acid                 | $\text{OH.C}_6\text{H}_4(\text{H}_6)\text{COOH}$                           | 144.13          | $\text{C}_7\text{H}_{10}\text{O}_3$       |
| 29 — toluene                        | $\text{C}_6\text{H}_5(\text{H}_6)\text{CH}_3$                              | 98.15           | $\text{C}_7\text{H}_{14}$                 |
| 30 — <i>m</i> xylene                | $\text{C}_6\text{H}_4(\text{H}_6)(\text{CH}_3)_2$                          | 112.17          | $\text{C}_8\text{H}_{16}$                 |
| 31 Hexa hydroxy benzene             | $\text{C}_6(\text{OH})_6$  | 174.08          | $\text{C}_6\text{H}_6\text{O}_6$          |
| 32 — methyl benzene                 | $\text{C}_6(\text{CH}_3)_6$  | 162.20          | $\text{C}_{12}\text{H}_{18}$              |
| 33 — methylene tetramine            | $(\text{CH}_2)_6\text{N}_4.6\text{H}_2\text{O}$                            | 248.27          | $\text{C}_6\text{H}_{12}\text{N}_4$       |



| Density<br>$H_2O=1$ . | Solubility in |           |               | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------|---------------|-----------|---------------|-------------|-------------|----|
|                       | Water.        | Alcohol.  | Ether.        |             |             |    |
| 0.6886/15°            |               | s.        | s.            | liq.        | 97.5—98.5   | 1  |
| 0.6819/17°            |               | s.        | s.            | liq.        | 90.3        | 2  |
| 0.689/27°             |               | s.        | s.            | liq.        | 95—98       | 3  |
| 0.711/0°              |               | s.        | s.            | liq.        | 87          | 4  |
| 0.8031/20°            |               |           |               | liq.        | 110—112     | 5  |
| 0.830/16°             | i.            | s.        | s.            | — 35.5      | 172.5—173   | 6  |
| 0.8200/20°            |               | s.        | s.            | liq.        | 154—155     | 7  |
| 0.8288/20°            | v.s.s.        | s.        | s.            | liq.        | 131—132     | 8  |
| 0.8402/20°            | s.s.          | s.        | s.            | liq.        | 143—144     | 9  |
|                       | s.s.          | s.        | s.            | liq.        | 130—133     | 10 |
|                       |               | s.        | s.            | 17          | 131         | 11 |
| 0.827/17°             | s.s.          | s.        |               | liq.        | 155         | 12 |
| 0.703/19°             |               | s.        |               | liq.        | 98—99       | 13 |
| 0.9345/0°             |               | s.        |               | — 12        | 221.5       | 14 |
|                       | 1 : 100 c.    |           |               | liq.        | 211.5/746   | 15 |
| 0.8716/20°            |               |           |               | liq.        | 188         | 16 |
| 0.92/11°              |               |           |               | 17          | 268—271     | 17 |
|                       | 1 : 5000 h.   | s.s.      | i.            | d. 251      |             | 18 |
| 1.569/236°            | s. $C_6H_6$ . | h.s.s.    | s.s.          | 227         | 326         | 19 |
| 2.011                 | i.            | s.        | s.            |             | 187         | 20 |
| 0.7754/18°            |               | m.        | m.            | 20          | 287.5       | 21 |
|                       | i.            | s.        | v.s.          | 129         | 305         | 22 |
|                       |               |           |               |             |             | 23 |
|                       | s.s.          | s.        | s.            | 30          | 232—233     | 24 |
| 0.787/20°             |               |           |               |             | 137         | 25 |
| 0.8116/17°            |               |           |               | liq.        | 153—158     | 26 |
|                       |               |           |               |             |             | 27 |
|                       | s.            | s.        | s.            | 111         |             | 28 |
| 0.772/4°              |               |           |               |             | 101         | 29 |
| 0.78/0°               |               |           |               |             | 119.5—120   | 30 |
|                       | s.s.          | s.s.      | s.s.          | 200 d.      |             | 31 |
|                       |               | s.s.      | v.s. $C_6H_6$ | 164 subl.   | 264         | 32 |
|                       | s.            | 1 : 14 c. | s. ac         | 15          | d.          | 33 |
|                       |               | 1 : 7 h.  |               |             |             |    |

| Name.                                 | Formula.   | Formula Weight. | Empirical Formula.                               |
|---------------------------------------|--|-----------------|--|
| 1 Hexane, 1. norm.                    | $\text{CH}_3(\text{CH}_2)_4\text{CH}_3$                                      | 86.14           | $\text{C}_6\text{H}_{14}$                        |
| 2 —, 2. ethyl isobutyl                | $\text{C}_2\text{H}_5\text{CH}_2\text{CH}:(\text{CH}_3)_2$                   | 86.14           | "  |
| 3 —, 3. di-isopropyl                  | $(\text{CH}_3)_2\text{CH}:\text{CH}:\text{CH}:(\text{CH}_3)_2$               | 86.14           | "  |
| 4 —, 4. trimethyl ethyl methane       | $\text{CH}_3)_3\text{C}:(\text{C}_2\text{H}_5)$                              | 86.14           | "  |
| 5 Hexa nitro diphenyl-amine           | $[\text{C}_6\text{H}_2(\text{NO}_2)_3]_2\text{NH}$                           | 439.17          | $\text{C}_{12}\text{H}_5\text{O}_{12}\text{N}_7$ |
| 6 Hexine, diallyl                     | $\text{CH}_2:\text{CH}:\text{CH}_2\text{CH}_2:\text{CH}:\text{CH}_2$         | 82.11           | "  |
| 7 Hexyl alcohol, 1. norm              | $\text{CH}_3(\text{CH}_2)_4\text{CH}_2\text{OH}$                             | 102.14          | $\text{C}_6\text{H}_{14}\text{O}$                |
| 8 —, 2. methyl butyl carbinol         | $\text{CH}_3\text{CHOH}:(\text{CH}_2)_3\text{CH}_3$                          | 102.14          | "  |
| 9 —, 3. ethyl propyl carbinol         | $\text{C}_2\text{H}_5\text{CHOH}:(\text{CH}_2)_2\text{CH}_3$                 | 102.14          | "  |
| 10 —, 4. pinacolyl alcohol            | $(\text{CH}_3)_3\text{CCHOHCH}_3$  | 102.14          | "  |
| 11 —, 5. dimethyl propyl carbinol     | $(\text{CH}_3)_2\text{CHOH}:(\text{CH}_2)_3\text{CH}_3$                      | 102.14          | "  |
| 12 —, 6. dimethyl iso propyl carbinol | $(\text{CH}_3)_2\text{CHOH}:\text{CH}:(\text{CH}_3)_2$                       | 102.14          | "  |
| 13 —, 7. diethyl methyl carbinol      | $(\text{C}_2\text{H}_5)_2\text{CHOHCH}_3$                                    | 102.14          | "  |
| 14 — aldehyde iso.                    | $(\text{CH}_3)_2\text{CH}:(\text{CH}_2)_3\text{CHO}$                         | 100.13          | $\text{C}_6\text{H}_{12}\text{O}$                |
| 15 Hexylene, $\beta$                  | $\text{CH}_3(\text{CH}_2)_2\text{CH}:\text{CH}:\text{CH}_3$                  | 84.13           | $\text{C}_6\text{H}_{12}$                        |
| 16 — glycol, 1. norm.                 | $\text{CH}_2(\text{CH}_2)_3\text{CHOHCH}_2\text{OH}$                         | 118.14          | $\text{C}_6\text{H}_{14}\text{O}_2$              |
| 17 —, 2. diallyl hydrate              | $(\text{CH}_3\text{CHCH}_2\text{OH})_2$                                      | 118.14          | "  |
| 18 —, 3. pinacone                     | $(\text{CH}_3)_2:(\text{C.OH})_2:(\text{CH}_3)_2$                            | 118.14          | "  |
| 19 — iodide                           | $\text{C}_6\text{H}_{12}\text{I}_2$  | 337.94          | $\text{C}_6\text{H}_{12}\text{I}_2$              |
| 20 Hippuric acid                      | $\text{C}_6\text{H}_5\text{CO.NH.CH}_2\text{COOH}$                           | 179.14          | $\text{C}_9\text{H}_9\text{O}_3\text{N}$         |
| 21 Homatropine                        | $\text{C}_{16}\text{H}_{21}\text{NO}_3$                                      | 275.27          | $\text{C}_{16}\text{H}_{21}\text{O}_3\text{N}$   |
| 22 Homocinchonine                     | $\text{C}_{19}\text{H}_{22}\text{N}_2\text{O}$                               | 294.29          | $\text{C}_{19}\text{H}_{22}\text{ON}_2$          |
| 23 Homophthalic acid                  | $\text{HOOC.C}_6\text{H}_4\text{CH}_2\text{COOH}$                            | 180.11          | $\text{C}_9\text{H}_8\text{O}_4$                 |
| 24 Homopyrrole, see                   | Methyl pyrrole   |                 |  |
| 25 Homosalicylic acid, see            | Hydroxy toluid acid, 2:1:3   |                 |  |
| 26 Hydantoic acid                     | $\text{NH}_2\text{CO.NH.CH}_2\text{COOH}$                                    | 118.08          | $\text{C}_3\text{H}_6\text{O}_3\text{N}_2$       |
| 27 Hydantoin                          | $\text{CO} \begin{array}{c} \text{NH.CH}_2 \\   \\ \text{NH.CO} \end{array}$ | 100.07          | $\text{C}_3\text{H}_4\text{O}_2\text{N}_2$       |
| 28 Hydracetamide                      | $(\text{CH}_3\text{CH})_3\text{N}_2$   | 112.15          | $\text{C}_5\text{H}_{12}\text{N}_2$              |
| 29 Hydracrylic acid                   | $\text{CH}_2\text{OHCH}_2\text{COOH}$  | 90.06           | $\text{C}_3\text{H}_6\text{O}_3$                 |

| Density<br>H <sub>2</sub> O=1. | Solubility in |             |             | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|---------------|-------------|-------------|-------------|-------------|----|
|                                | Water.        | Alcohol.    | Ether.      |             |             |    |
| 0.6630/17°                     |               | s.          | s.          | S.P. -94.3  | 68.8        | 1  |
| 0.7011/0°                      |               | s.          | s.          | liq.        | 62          | 2  |
| 0.67/17°                       |               | s.          | s.          | liq.        | 58.1        | 3  |
|                                |               | s.          | s.          | liq.        | 49.5        | 4  |
|                                | i.            | i.          | s alk       | 236 d.      |             | 5  |
| 0.6983/12°                     |               |             |             | liq.        | 59          | 6  |
| 0.8204/20°                     | s.s.          | s.          |             | liq.        | 157.2/741   | 7  |
| 0.8327/0°                      | v.s.s.        | s.          |             | liq.        | 136         | 8  |
| 0.8188/20°                     | v.s.s.        | s.          |             | liq.        | 135         | 9  |
| 0.8347/0°                      |               | s.          |             | 4           | 121—123     | 10 |
|                                |               | s.          |             | 4           | 120—125     | 11 |
| 0.8232/19°                     | s.            | s.          |             | - 35        | 117—119     | 12 |
| 0.8237/20°                     |               | s.          |             |             | /740mm. •   | 13 |
|                                | s.s.          | s.          |             | liq.        | 121/743     | 14 |
| 0.6997/0°                      |               |             |             | - 98.5      | 67.7—68.1   | 15 |
| 0.967/0°                       | s.            | s.          |             | liq.        | 207         | 16 |
| 0.9638/0°                      |               |             |             | liq.        | 212—215     | 17 |
| 0.96719/15°                    | h.s.          | h.s.        |             | 43—44       | 171—172     | 18 |
| 2.024/0°                       |               |             |             | liq.        | d.          | 19 |
| 1.308                          | h.s.          | h.s.        | s.s.        | 189         | d.          | 20 |
|                                | s.s.          |             |             | 99—100      |             | 21 |
|                                | s.s.          | 1 : 140/10° | 1 : 371/10° | 257—257     |             | 22 |
|                                |               | v.s.        |             | 175—176     |             | 23 |
|                                |               |             |             |             |             | 24 |
|                                |               |             |             |             |             | 25 |
|                                | c.s.s.        | h.s.        | v.s.s.      | 153—156 d.  |             | 26 |
|                                | h.s.          | s.          |             | 218—220     |             | 27 |
|                                | s.            | s.          |             |             |             | 28 |
|                                | h.s.          | s.          | s.          | liq.        | d.          | 29 |

| Name.                             | Formula.  | Formula Weight. | Empirical Formula.   |
|-----------------------------------|---|-----------------|----------------------|
| 1 Hydratropic acid                | $C_6H_5.CH(CH_3)COOH$   | 150.13          | $C_9H_{10}O_2$       |
| 2 Hydrazo benzene                 | $C_6H_5.NH.NH.C_6H_5$   | 148.18          | $C_{12}H_{12}N_2$    |
| 3 — benzoic acid, <i>o</i>        | $(NH.C_6H_4.COOH)_2$  | 272.19          | $C_{14}H_{12}O_4N_2$ |
| 4 — — —, <i>m</i> .               | " " "   | 272.19          | " "                  |
| 5 — toluene, <i>o</i>             | $CH_3.C_6H_4.NH.NH.C_6H_4.CH_3$   | 212.22          | $C_{14}H_{16}N_2$    |
| 6 — — —, <i>m</i>                 | " " "   | 212.22          | " "                  |
| 7 — — —, <i>p</i>                 | " " "   | 212.22          | " "                  |
| 8 Hydrindene, 2 : 3               | $C_6H_4 : (CH_2)_3$   | 118.13          | $C_9H_{10}$          |
| 9 Hydrindone, $\alpha$            | $C_6H_4 \begin{array}{c} \diagup CH_2 \\ \diagdown CO \end{array} CH_2$     | 132.11          | $C_9H_8O$            |
| 10 —, $\beta$                     | $C_6H_4 \begin{array}{c} \diagup CH_2 \\ \diagdown CO \end{array} CO$       | 132.11          | "                    |
| 11 Hydro-acridine, 5 : 10         | $C_6H_4 \begin{array}{c} \diagup CH_2 \\ \diagdown NH \end{array} C_6H_4$   | 181.16          | $C_{13}H_{11}N$      |
| 12 — anthranol, 10 : 9 : 10       | $CH_2 \begin{array}{c} \diagup C_6H_4 \\ \diagdown C_6H_4 \end{array} CHOH$ | 196.17          | $C_{14}H_{12}O$      |
| 13 — benzamide                    | $(C_6H_5.CH)_3N$  | 298.27          | $C_{21}H_{18}N_2$    |
| 14 — benzoin                      | $C_6H_5.(CHOH)_2.C_6H_5$  | 214.18          | $C_{14}H_{14}O_2$    |
| 15 — carbostyryl                  | $C_9H_9NO$  | 147.13          | $C_9H_9ON$           |
| 16 — cinnamic acid                | $C_6H_5.CH_2.CH_2COOH$  | 150.13          | $C_9H_{10}O_2$       |
| 17 — cœrulignone                  | $(HO)_2 : C_{12}H_4(OCH_3)_4$   | 306.22          | $C_{16}H_{18}O_6$    |
| 18 — coumaric acid, <i>o</i>      | $OH.C_6H_4.(CH_2)_2.COOH$   | 166.13          | $C_9H_{10}O_3$       |
| 19 — — —, <i>p</i>                | " " "   | 166.13          | " "                  |
| 20 — cyanic acid                  | $HCN$   | 27.02           | $CHN$                |
| 21 — mellitic acid                | $C_6H_6(COOH)_6$  | 348.16          | $C_{12}H_{12}O_{12}$ |
| 22 — phenazine, 5 : 10            | $C_6H_4 : (NH)_2 : C_6H_4$  | 182.16          | $C_{12}H_{10}N_2$    |
| 23 — quinone, see                 | Dihydroxy benzene   |                 |                      |
| 24 — — phthalein                  | $C_{20}H_{12}O_5$   | 332.20          | $C_{20}H_{12}O_5$    |
| 25 Hydroxy acetophenone, <i>o</i> | $C_6H_4(OH).COCH_3$   | 136.10          | $C_8H_8O_2$          |
| 26 — — —, <i>m</i>                | $C_6H_4(OH).COCH_3$   | 136.10          | $C_8H_8O_2$          |
| 27 — — —, <i>p</i>                | " " "   | 136.10          | " "                  |
| 28 — — — carboxylic acid          | see Acetyl hydroxy benzoic acid   |                 |                      |
| 29 — acrylic acid, $\beta$        | $CHOH : CH.COOH$  | 88.05           | $C_3H_4O_3$          |
| 30 — anthraquinone, 1             | $C_6H_4 : (CO)_2 : C_6H_3OH$  | 224.13          | $C_{14}H_8O_3$       |
| 31 — — —, 2                       | " " "   | 224.13          | " "                  |

| Density<br>H <sub>2</sub> O=1. | Solubility in— |             |         | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|----------------|-------------|---------|-------------|-------------|----|
|                                | Water.         | Alcohol.    | Ether.  |             |             |    |
| 1.150                          | i.             | 5 : 100/16° | s.      | liq.        | 264—265     | 1  |
|                                |                | h.s.        |         | 131         | d.          | 2  |
|                                |                | h.s.s.      | s. alk. |             |             | 3  |
|                                | i.             | s.          | s.      | 156         | d.          | 4  |
|                                |                | v.s.        |         | liq.        |             | 5  |
|                                |                | s.          | s.      | 124         | d.          | 6  |
|                                |                |             |         |             | 176—176.5   | 7  |
| 0.957/15                       |                |             |         |             |             | 8  |
| 1.011/45°                      | s.s.           | v.s.        |         | 41—42       | 243—245     | 9  |
|                                |                | s.          | s.      | 61          | 220—225     | 10 |
|                                | i.             | h.s.        | s.      | 169         | subl.       | 11 |
|                                | h.s.           | s.          | s.      | 76          |             | 12 |
|                                | i.             | s.          | s.      | 110         |             | 13 |
|                                | 1:400/15°      | h.s.        |         | 138         |             | 14 |
|                                | i.             | s.          | s.      | 163         |             | 15 |
|                                | 1:168/20°      | s.          | s.      | 48.7        | 279         | 16 |
|                                | v.s.s.         | h.s.        | v.s.s.  | 190         |             | 17 |
|                                | 1:20/18°       | s.          | s.      | 82—83       |             | 18 |
| 0.697/18°                      | h.s.           | s.          | s.      | 128         |             | 19 |
|                                | m.             | m.          | m.      | — 14        | 26.11       | 20 |
|                                |                | s.s.        |         | d.          |             | 21 |
|                                |                |             |         |             |             | 22 |
|                                |                |             |         |             |             | 23 |
|                                | h.v.s.s.       | s.          |         | 232—234     | d.          | 24 |
|                                | h.v.s.         | v.s.        | v.s.    |             | 96—97/10    | 25 |
|                                |                |             |         | 95—96       |             | 26 |
|                                |                |             |         | 110         |             | 27 |
|                                |                |             |         |             |             | 28 |
|                                | s.             | s.          | s.      | liq         |             | 29 |
|                                | s. alk.        | s.          | s.      | 190         | subl.       | 30 |
|                                | h.s.           | v.s.        | v.s.    | 302         | subl.       | 31 |

| Name. |                                 | Formula                     | Formula Empirical<br>Weight. Formula. |
|-------|---------------------------------|-----------------------------|---------------------------------------|
| 1     | Hydroxy azobenzene, 4           | $C_6H_5.N_2.C_6H_4OH$       | 198.16 $C_{12}H_{10}ON_2$             |
| 2     | —, 2                            | " "                         | 198.16 "                              |
| 3     | — benzaldehyde, <i>o</i>        | $HO.C_6H_4.CHO$             | 122.08 $C_7H_6O_2$                    |
| 4     | —, <i>m</i>                     | " "                         | 122.08 "                              |
| 5     | —, <i>p</i>                     | " "                         | 122.08 "                              |
| 6     | — benzoic acid, <i>o</i>        | $C_6H_4OH.COOH$             | 138.08 $C_7H_6O_3$                    |
| 7     | —, <i>m</i>                     | " "                         | 138.08 "                              |
| 8     | —, <i>p</i>                     | " " $(H_2O)$                | 138.08 "                              |
| 9     | — benzyl alcohol, <i>o</i>      | $HO.C_6H_4.CH_2OH$          | 124.10 $C_7H_8O_2$                    |
| 10    | —, <i>m</i>                     | " "                         | 124.10 "                              |
| 11    | —, <i>p</i>                     | " "                         | 124.10 "                              |
| 12    | — butyric acid, $\alpha$        | $C_3H_5.CHOH.COOH$          | 104.08 $C_4H_8O_3$                    |
| 13    | —, $\beta$                      | $CH_3.CHOH.CH_2.COOH$       | 104.08 "                              |
| 14    | —, $\gamma$                     | $CH_3.OH.(CH_2)_2.COOH$     | 104.08 "                              |
| 15    | —, acetone acid                 | $(CH_3)_2:COH.COOH$         | 104.08 "                              |
| 16    | — caproic acid                  | $C_5H_{10}(OH).COOH$        | 132.13 $C_6H_{12}O_3$                 |
| 17    | —, diethyl glycollic acid       | $(C_2H_5)_2:O(OH)COOH$      | 132.13 "                              |
| 18    | —, $\alpha$                     | $CH_3.(CH_2)_3.CHOH.COOH$   | 132.13 "                              |
| 19    | — caprylic acid, $\alpha$       | $CH_3.(CH_2)_5.CHOH.COOH$   | 160.17 $C_{18}H_{16}O_3$              |
| 20    | — citric acid                   | $C_3H_3(OH)_2(COOH)_3.H_2O$ | 228.11 $C_6H_8O_8$                    |
| 21    | — diphenyl, 4                   | $C_6H_5.C_6H_5OH$           | 170.14 $C_{12}H_{10}O$                |
| 22    | — diphenylamine, 4              | $C_6H_5.NH.C_6H_5OH$        | 185.16 $C_{12}H_{11}ON$               |
| 23    | —, 3                            | " "                         | 185.16 "                              |
| 24    | — ethyl amine, see              | Amino ethyl alcohol         |                                       |
| 25    | — piperidine                    | $C_5H_{10}N.C_2H_4OH$       | 129.17 $C_7H_{15}ON$                  |
| 26    | — glutaric acid, $\alpha$       | $C_3H_5(OH)(COOH)_2$        | 148.09 $C_5H_8O_5$                    |
| 27    | — hydroquinone, 1:2:4           | $C_6H_3(OH)_3$              | 126.08 $C_6H_6O_3$                    |
| 28    | — triethyl ether, 1:2:4         | $C_6H_3(OC_2H_5)_3$         | 210.22 $C_{12}H_{18}O_3$              |
| 29    | — isocaprolic acid              | $[(CH_3)_2:CH]_2:COH.COOH$  | 160.17 $C_8H_{16}O_3$                 |
| 30    | — methyl benzoic acid, <i>o</i> | $OH_2OH.C_6H_4.COOH$        | 152.10 $C_8H_8O_3$                    |
| 31    | — naphthoquinone, 1:4:5         | $C_{10}H_5O_2.OH$           | 174.10 $C_{10}H_6O_3$                 |
| 32    | —, 1:4:2                        | " "                         | 174.10 "                              |
| 33    | — naphthoic acid, $OH:COOH=1:2$ | $C_{10}H_6OH.COOH$          | 188.12 $C_{11}H_8O_3$                 |

| Density<br>H <sub>2</sub> O=1. | Solubility in            |                |                          | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|--------------------------|----------------|--------------------------|-------------|-------------|----|
|                                | Water.                   | Alcohol.       | Ether.                   |             |             |    |
|                                | h.v.s.s.                 | v.s.           | v.s.                     | 152         |             | 1  |
|                                |                          |                |                          | 82          |             | 2  |
| 1.1520/15°                     | s.                       | m.             | m.                       | - 21        | 196.5       | 3  |
|                                | h.s.                     | s.             | s.                       | 107         | 240         | 4  |
|                                | c.s.s.                   | s.             | s.                       | 116         | subl.       | 5  |
| 1.4835/4°                      | 8:100/100°               | 1:2/15°        | s.                       | 156.5       |             | 6  |
| 1.473/4°                       | 0.843:100/18.8°          |                | s.                       | 199.8       |             | 7  |
| 1.468/4°                       | 0.942:100/20°            | s.             | s.                       | 215         | d.          | 8  |
| 1.1613/25°                     | 1:15/22°                 | v.s.           | v.s.                     | 86          | subl.       | 9  |
|                                | h.m.                     |                |                          |             |             |    |
|                                | h.s.                     | s.             | s.                       | 67          | 300 d.      | 10 |
|                                | s.                       | s.             | s.                       | 110         |             | 11 |
|                                |                          |                |                          | 42          | 225 d.      | 12 |
|                                |                          |                |                          |             |             | 13 |
|                                |                          |                |                          | liq. —17    |             | 14 |
|                                | v.s.                     | v.s.           | v.s.                     | 79          | 212         | 15 |
|                                | v.s.                     | v.s.           | v.s.                     | 72.5—73.5   | subl.       | 16 |
|                                | 1:2.85/<br>17.5°         | s              | s.                       | 80          | subl. 50    | 17 |
|                                |                          |                |                          | 60—62       |             | 18 |
|                                | v.s.s.                   | v.s.           | v.s.                     | 69.5        |             | 19 |
|                                | v.s.                     | v.s.           | v.s.                     | 159—160     |             | 20 |
|                                | h.s.                     | s.             | s., s. CHCl <sub>3</sub> | 160—162     | 305—308     | 21 |
|                                | c.v.s.s.                 | s.             | s.                       | 70          | 330         | 22 |
|                                | h.s.s.                   | s              | s.                       | 81.5—82     | 34°         | 23 |
|                                |                          |                |                          |             |             | 24 |
|                                | m.                       | s.             |                          | liq.        | 199         | 25 |
|                                | s.                       | s.             |                          | 72—73       |             | 26 |
|                                | v.s.                     | v.s.           | v.s.                     | 140.5       |             | 27 |
|                                |                          |                |                          | 34          |             | 28 |
|                                | s.s.                     | s.             | s.                       | 110—111     |             | 29 |
|                                | 1:43/20°                 | s.             | s.                       | 120         |             | 30 |
|                                | i., s. CHCl <sub>3</sub> | s., s. acetic. | s.s.                     | 151—154     |             | 31 |
|                                | h.s.s.                   | s.             | s.                       | d. 190      | subl.       | 32 |
|                                | h.s.s.                   | s.s.           | s.s.                     | 186         |             | 33 |

| Name.                                | Formula.  | Formula Weight. | Empirical Formula. |
|--------------------------------------|---|-----------------|--------------------|
| 1 Hydroxy naphthoic acid, 5:1        | $C_{10}H_6OH.COOH$  | 188.12          | $C_{11}H_8O_3$     |
| 2 ———, 8:1                           | " "   | 188.12          | "                  |
| 3 ———, 7:2                           | " "   | 188.12          | "                  |
| 4 ———, 2:1                           | " "   | 188.12          | "                  |
| 5 ———, 3:2                           | " "   | 188.12          | "                  |
| 6 — nicotinic acid, <i>p</i>         | $C_5H_3N(OH).COOH$  | 139.08          | $C_6H_5O_3N$       |
| 7 — phenyl acetic acid, <i>o</i>     | $HO.C_6H_4.CH_2.COOH$   | 152.10          | $C_8H_8O_3$        |
| 8 ———, <i>m</i>                      | " "   | 152.10          | "                  |
| 9 ———, <i>p</i>                      | " "   | 152.10          | "                  |
| 10 — ethylamine, <i>p</i>            | $OH.C_6H_4.C_2H_4.NH_2$   | 137.14          | $C_8H_{11}ON$      |
| 11 — propiolic acid, <i>p</i>        | $OH.C_6H_4.C : C.COOH$  | 162.09          | $C_9H_6O_3$        |
| 12 — phthalic acid,<br>COOH:COOH:OH= |   |                 |                    |
| 13 1:2:3                             | $C_8H_3(OH)(COOH)_2$  | 182.09          | $C_8H_6O_3$        |
| 14 1:2:4                             | " "   | 182.09          | "                  |
| 15 1:3:2                             | " " $.H_2O$   | 200.11          | "                  |
| 16 1:3:4                             | " "   | 182.09          | "                  |
| 17 1:3:5                             | " "   | 182.09          | "                  |
| 18 1:4:3                             | " "   | 182.09          | "                  |
| 19 — pyridine, $\alpha$ pyridone     | $CH \begin{array}{c} \diagup CH.C(OH) \diagdown \\ CH:CH \\ \diagdown C(OH).CH \diagup \end{array} N$   | 95.08           | $C_5H_5ON$         |
| 20 —, $\beta$ pyridone               | $CH \begin{array}{c} \diagup C(OH).CH \diagdown \\ CH:CH \\ \diagdown CH:CH \diagup \end{array} N$      | 95.08           | "                  |
| 21 —, $\gamma$ pyridone              | $C(OH) \begin{array}{c} \diagup CH:CH \diagdown \\ CH:CH \\ \diagdown CH:CH \diagup \end{array} N.H_2O$ | 113.10          | "                  |
| 22 — quinaldine, 8:2                 | $C_{10}H_9NO$   | 159.13          | $C_{10}H_9ON$      |
| 23 —, 6:2                            | "   | 159.13          | "                  |
| 24 —, 5:2                            | "   | 159.13          | "                  |
| 25 —, 4:2                            | " $.2H_2O$  | 195.16          | "                  |
| 26 — quinoline, 8                    | $C_9H_7NO$  | 145.11          | $C_9H_7ON$         |



| Density<br>$H_2O=1$ . | Solubility in |             |        | M.P.<br>°C. | B.P.<br>°C. |
|-----------------------|---------------|-------------|--------|-------------|-------------|
|                       | Water.        | Alcohol.    | Ether. |             |             |
| v.s.                  |               |             |        | 219         | 1           |
| s.s.                  | v.s.          | v.s.        |        | 169         | 2           |
| v.s.s.                | v.s.s.        | v.s.s.      |        | 245         | 3           |
| v.s.                  | v.s.s. (abs.) |             |        | 156 d.      | 4           |
| i.                    | s.s.          | s.s.        |        | 216         | 5           |
| h.s.s.                | v.s.s.        | v.s.s.      |        | d. 301—302  | 6           |
| s.                    |               | s.          |        | 137         | 7           |
| v.s.                  | v.s.          | v.s.        |        | 128.5       | 8           |
| h.v.s.                | v.s.          | v.s.        |        | 145         | 9           |
| c.s.s.                | 1: 10 h.      | s. $C_6H_6$ |        | 161—163     | 10          |
| h.s.                  | s.            |             |        | 192—193     | 11          |
|                       |               |             |        |             | 12          |
| 1: 5/17°              | v.s.          | v.s.        |        | 150         | 13          |
| 1: 32/10°             | s.            | s.          |        | 181         | 14          |
| 1: 40/100°            | s.            | s.          |        | 239, an.    | 15          |
|                       |               |             |        | 243—244     |             |
| c.v.s.s.              | v.s.          | s.          |        | 305—306     | 16          |
| 1: 5.4/100°           | s.            | s.          |        | 288         | 17          |
| h.s.s.                | s.            | s.          |        | subl.       | 18          |
| v.s.                  | v.s.          | s.          |        | 106—107     | 19          |
|                       |               |             |        | 280—281     |             |
| s.                    | s.            |             |        | 129         | 20          |
|                       |               |             |        |             |             |
| 1: 1/15°              | s.            | v.s.s.      |        | 66, an.     | 21          |
|                       |               |             |        | 148.5       |             |
| s.s.                  | h.s.          | s.          |        | 74          | 22          |
|                       |               |             |        | 266—267     |             |
|                       |               |             |        | subl.       |             |
| v.s.s.                | s.            | s.          |        | 213         | 23          |
| i.                    | h.s.          | s.          |        | 232—234     | 24          |
| 1: 100 c.             | s.            | i.          |        | 231         | 25          |
| 0.48: 100             | s.            | s.s.        |        | 75.8        | 26          |
| /15°                  |               |             |        | 266.6/      |             |
|                       |               |             |        | 752mm.      |             |

| Name.                      | Formula.  | Formula Weight. | Empirical Formula.    |
|----------------------------|---|-----------------|-----------------------|
| 1 Hydroxy quinoline, 2     | $C_9H_7NO$  | 145.11          | $C_9H_7ON$            |
| 2 —, 6                     | "   | 145.11          | "                     |
| 3 —, carbostyrl            | "   | 145.11          | "                     |
| 4 — salicylic acid, see    | Dihydroxy benzoic acid  |                 |                       |
| 5 — stearic acid, $\alpha$ | $C_{18}H_{36}O_2$   | 300.38          | $C_{18}H_{36}O_2$     |
| 6 — —, $\beta$             | "   | 300.38          | "                     |
| — toluic acid,             |   |                 |                       |
| COOH:CH <sub>3</sub> :OH = |   |                 |                       |
| 7 2:1:3                    | $CH_3.C_6H_3(OH)COOH$   | 152.10          | $C_8H_8O_3$           |
| 8 2:1:6                    | " "   | 152.10          | "                     |
| 9 2:1:4                    | " "   | 152.10          | "                     |
| 10 2:1:5                   | " " $\frac{1}{2}H_2O$   | 161.11          | "                     |
| 11 3:1:2                   | " "   | 152.10          | "                     |
| 12 3:1:4                   | " "   | 152.10          | "                     |
| 13 3:1:5                   | " "   | 152.10          | "                     |
| 14 3:1:6                   | " " $\frac{1}{2}H_2O$   | 161.11          | "                     |
| 15 4:1:2                   | " "   | 152.10          | "                     |
| 16 4:1:3                   | " "   | 152.10          | "                     |
| 17 Hypogæic acid,          | $C_{15}H_{29}COOH$  | 254.32          | $C_{16}H_{30}O_2$     |
| physetoleic acid           |   |                 |                       |
| 18 Hypoxanthine            | $C_5H_4N_4O$  | 136.10          | $C_5H_4ON_4$          |
| 19 Hystazarin, see         | Dihydroxy anthraquinone   |                 |                       |
| 20 Imesatine               | $C_6H_4 \begin{array}{c} \diagup C:(NH) \diagdown \\ \diagdown NH \diagup \end{array} CO$   | 146.11          | $C_8H_6ON_2$          |
| 21 Indene                  | $C_6H_4 \begin{array}{c} \diagup CH \diagdown \\ \diagdown CH_2 \diagup \end{array} CH$   | 116.11          | $C_9H_8$              |
| 22 Indican                 | $C_{26}H_{31}NO_{17}$   | 629.39          | $C_{26}H_{31}O_{17}N$ |
| 23 Indigotin               | $C_6H_4 \begin{array}{c} \diagup CO \diagdown \\ \diagdown NH \diagup \end{array} C:C \begin{array}{c} \diagup CO \diagdown \\ \diagdown NH \diagup \end{array} C_6H_4$ | 262.18          | $C_{16}H_{10}O_2N_2$  |
| 24 Indin                   | $C_{16}H_{10}N_2O_2$  | 262.18          | "                     |
| 25 Indole                  | $C_6H_4 \begin{array}{c} \diagup CH \diagdown \\ \diagdown NH \diagup \end{array} CH$   | 117.11          | $C_8H_7N$             |
| 26 Indophenine             | $C_{12}H_7ONS$  | 213.19          | $C_{12}H_7ONS$        |

| Density<br>H <sub>2</sub> O=1. | Solubility in |                    |                      | M.P.<br>°C. | B.P.<br>°C.           |    |
|--------------------------------|---------------|--------------------|----------------------|-------------|-----------------------|----|
|                                | Water.        | Alcohol.           | Ether.               |             |                       |    |
|                                |               |                    | s.s.                 | 199—200 d.  |                       | 1  |
|                                | h.s.          | s.s.               | v.s.s.               | 193—195     | >360                  | 2  |
|                                | h.s.          | v.s.               | v.s.                 | 199—200     | subl.                 | 3  |
|                                |               |                    |                      |             |                       | 4  |
|                                |               | 0.58 : 100<br>/20° | s.                   | 75          |                       | 5  |
|                                |               |                    |                      | 81—81.5     |                       | 6  |
|                                | h.s.          | v.s.               | v.s.                 | 168         |                       | 7  |
|                                | h.s.          | v.s.               | v.s.                 | 183         |                       | 8  |
|                                | c.s.          | v.s.               | v.s.                 | 172         |                       | 9  |
|                                | h.s.          | v.s.               | v.s.                 | 177—178     |                       | 10 |
|                                | h.s.          | v.s.               | s. CHCl <sub>3</sub> | 163—164     |                       | 11 |
|                                | c.s.          | v.s.               | v.s.                 | 150         |                       | 12 |
|                                | h.s.          | s.                 | s.                   | 208         | subl                  | 13 |
|                                | h.s.          | s.                 | s.                   | 172—173     |                       | 14 |
|                                | h.s.          | s.                 | s.                   | 206—207     |                       | 15 |
|                                | i.            | h.s.               | s.                   | 177         |                       | 16 |
|                                | i.            | s.                 | s.                   | 33          |                       | 17 |
|                                | 1:300 c       | s.s.               | l.                   |             | d                     | 18 |
|                                | h.s.          |                    |                      |             |                       | 19 |
|                                | i.            | h.s.               | s.s.                 |             |                       | 20 |
| 1.0059/4                       |               |                    |                      | - 2         | 161.3                 | 21 |
|                                |               | s.                 |                      | syrup.      | d.                    | 22 |
| 1.95                           | i.            | i.                 | s. aniline.          | 390—392 d   | subl. 156—158<br>/0mm | 23 |
|                                | i.            | h.s.s.             | s.s.                 |             |                       | 24 |
|                                | h.s.          | s.                 | s.                   | 52          | 253—254               | 25 |
|                                | l.            | v.s.s.             | v.s.s.               |             |                       | 26 |

| Name                          | Formula   | Formula Empirical,<br>Weight. Formula.            |
|-------------------------------|---|---|
| 1 Indoxyl                     | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{C(OH)} \\ \diagdown \text{NH} \end{array} \text{OH}$             | 133.11 $\text{C}_8\text{H}_7\text{ON}$            |
| 2 Indoxylic acid              | $\text{C}_9\text{H}_7\text{NO}_3$   | 177.11 $\text{C}_9\text{H}_7\text{O}_3\text{N}$   |
| 3 Indoxyl sulphuric acid      | $\text{C}_8\text{H}_7\text{NSO}_4$  | 213.17 $\text{C}_8\text{H}_7\text{O}_4\text{NS}$  |
| 4 Inosite, see                | Dambose   |   |
| 5 Inulin                      | $\text{C}_{36}\text{H}_{62}\text{O}_{31}$   | 990.68 $\text{C}_{36}\text{H}_{62}\text{O}_{31}$  |
| 6 Iodo acetic acid            | $\text{CH}_2\text{I.COOH}$  | 185.95 $\text{C}_2\text{H}_3\text{O}_2\text{I}$   |
| 7 — acetate, ethyl            | $\text{CH}_2\text{I.COOC}_2\text{H}_5$  | 214.00 $\text{C}_4\text{H}_7\text{O}_2\text{I}$   |
| 8 — aniline, <i>m</i>         | $\text{C}_6\text{H}_4\text{I.NH}_2$   | 219.01 $\text{C}_6\text{H}_5\text{NI}$            |
| 9 — —, <i>p</i>               | "   | 219.01 "  |
| 10 — benzene                  | $\text{C}_6\text{H}_5\text{I}$  | 203.99 $\text{C}_6\text{H}_5\text{I}$             |
| 11 — propionic acid, $\alpha$ | $\text{CH}_3\text{CHI.COOH}$  | 199.98 $\text{C}_5\text{H}_9\text{O}_2\text{I}$   |
| 12 — — —, $\beta$             | $\text{CH}_2\text{I.CH}_2\text{COOH}$   | 199.98 "  |
| 13 Iodoform                   | $\text{CHI}_3$  | 393.77 $\text{CHI}_3$                             |
| 14 Iodoso benzene             | $\text{C}_6\text{H}_5\text{IO}$   | 219.99 $\text{C}_6\text{H}_5\text{OI}$            |
| 15 Iodoxy benzene             | $\text{C}_6\text{H}_5\text{IO}_2$   | 235.99 $\text{C}_6\text{H}_5\text{O}_2\text{I}$   |
| 16 Ionone                     | $\text{C}_{13}\text{H}_{20}\text{O}$  | 192.23 $\text{C}_{13}\text{H}_{20}\text{O}$       |
| 17 — semicarbazone, $\alpha$  | $\text{C}_{13}\text{H}_{20}:\text{N.NH.CO NH}_2$  | 249.26 $\text{C}_{14}\text{H}_{23}\text{ON}_3$    |
| 18 — —, $\beta$               | " "   | 249.28 "  |
| 19 Irone                      | $\text{C}_{13}\text{H}_{20}\text{O}$  | 192.23 $\text{C}_{13}\text{H}_{20}\text{O}$       |
| 20 Isatin                     | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{CO} \\ \diagdown \text{N} \end{array} \text{COH}$                | 147.09 $\text{C}_8\text{H}_5\text{O}_2\text{N}$   |
| 21 — anilide, $\alpha$        | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{CO} \\ \diagdown \text{NH} \end{array} \text{C:N.C}_6\text{H}_5$ | 222.17 $\text{C}_{14}\text{H}_{10}\text{ON}_2$    |
| 22 — chloride                 | $\text{C}_6\text{H}_5:\text{CO(N)}:\text{O.Cl}$   | 165.54 $\text{C}_7\text{H}_5\text{ONCl}$          |
| 23 Isatinic acid              | $\text{NH}_2\text{C}_6\text{H}_4\text{CO.COOH}$   | 165.11 $\text{C}_8\text{H}_7\text{O}_3\text{N}$   |
| 24 Isatoic anhydride          | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{CO.O} \\ \diagdown \text{NH.CO} \end{array}$                     | 163.09 $\text{C}_8\text{H}_5\text{O}_3\text{N}$   |
| 25 Isatoxime                  | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{C:NOH} \\ \diagdown \text{N:C.OH} \end{array}$                   | 162.11 $\text{C}_8\text{H}_6\text{O}_2\text{N}_2$ |
| 26 Isatropic acid             | $\text{C}_9\text{H}_8\text{O}_2$  | 148.11 $\text{C}_9\text{H}_8\text{O}_2$           |
| 27 Isethionic acid            | $\text{C}_2\text{H}_4(\text{OH})\text{SO}_3\text{H}$  | 126.12 $\text{C}_2\text{H}_6\text{O}_4\text{S}$   |

| Density<br>H <sub>2</sub> O=1. | Solubility in |               |                                      | M.P.<br>°C.         | B.P.<br>°C.        |             |
|--------------------------------|---------------|---------------|--------------------------------------|---------------------|--------------------|-------------|
|                                | Water.        | Alcohol.      | Ether.                               |                     |                    |             |
|                                |               |               | s. alk.                              | 85                  |                    | 1           |
|                                | s.s.          |               |                                      |                     | 122—123<br>subl. d | 2           |
|                                | s.            | h s           | i.                                   | d.                  |                    | 3           |
| 1.3491                         | s.s.          | s.s.          |                                      | d. 160<br>82        |                    | 4<br>5<br>6 |
|                                | i.            | s.            |                                      | 27                  | 178—180            | 7           |
|                                | i.            | s.            |                                      | 64                  |                    | 8           |
| 1.833/15°                      | i.            | s.            |                                      | - 28.5              | 188.2              | 9           |
|                                | v.s.s.        |               |                                      | 44.5—45.5           |                    | 10          |
|                                | h.s.          | v.s.          | v.s.                                 | 85                  |                    | 11          |
| 4.008/17°                      | i.            | s.            | s.                                   | 119                 | ubl. d             | 12          |
|                                | h.s.          | s.            | i.                                   | 105—106 d.          |                    | 13          |
|                                | h.s.          |               |                                      | 167                 |                    | 14          |
| 0.935/20°                      |               | s.            | s., s. C <sub>6</sub> H <sub>6</sub> |                     | 126—128<br>/12mm   | 15          |
|                                |               | v.s.s.ligroin |                                      | 117—118<br>148—149  |                    | 16          |
| 0.939/20°                      | v.s.s.        | s.            | s.                                   | liq.                | 144/16mm           | 17          |
|                                | h.s.          | s.            | s.                                   | 200—201             | subl.              | 18          |
|                                |               | h.s.          | s.                                   | 126                 |                    | 19          |
|                                | i.            | s.            | s. to B.                             | d. 180<br>d.        |                    | 20          |
|                                | s.s.          |               |                                      |                     |                    | 21          |
|                                |               | s.s.          | s s                                  | d. 230              |                    | 22          |
|                                | v.s.s.        | s.            |                                      | 202                 |                    | 23          |
|                                | h.v.s.s.      | s.s.          | i.                                   | 237—237.5<br>syrup. |                    | 24          |
|                                | v.s.          |               |                                      |                     |                    | 25          |

| Name.  | Formula.  | Formula Weight. | Empirical Formula. |
|--|---|-----------------|--------------------|
| 1 Iso-anthraflavic acid, see Dihydroxy anthraquinone |   |                 |                    |
| 2 Iso-cholesterin                                    | $C^{26}H^{43}OH$  | 372.48          | $C^{26}H^{44}O$    |
| 3 — benzoate   | $C^{26}H^{43}O.C^{7}H^{5}O$   | 476.55          | $C^{32}H^{48}O_2$  |
| 4 — cinchomeronic acid                               | $C^{26}H^{43}NO_4.H_2O$   | 185.11          | $C^{32}H^{48}O_5$  |
| 5 — citric acid                                      | $C_6H_8O_7$   | 192.09          | $C_6H_8O_7$        |
| 6 — coumarin   | $C_6H_4 \begin{cases} \text{CH:CH} \\   \\ \text{CO.O} \end{cases}$ | 146.09          | $C_9H_6O_2$        |
| 7 — crotonic acid                                    | $CH_2:CH.CH_2.COOH$   | 86.07           | $C^4H^6O_2$        |
| 8 — cymene   | $C^{10}H^{14}$  | 134.16          | $C^{10}H^{14}$     |
| 9 — dulcitol, rhamnose                               | $CH_3.(CHOH)_4.CHO.H_2O$  | 182.14          | $C_6H_{12}O_5$     |
| 10 — durene, 1 : 2 : 3 : 5                           | $C_6H_2(CH_3)_4$  | 134.16          | $C^{10}H^{14}$     |
| 11 — eugenol, 4 : 3 : 1                              | $C_6H_3(OH)(OCH_3)CH:CH.CH_3$                                       | 164.15          | $C^{10}H^{12}O_2$  |
| 12 — ferulic acid                                    | $C^7H^7O_2.C^2H^2.COOH$   | 194.13          | $C^{10}H^{10}O_4$  |
| 13 — glucosamine                                     | $C^6H^{11}O(NH_2)$  | 179.14          | $C^6H^{13}O_5N$    |
| 14 — hydrobenzoin                                    | $C^6H^5.CHOH.CHOH.C^6H_5$   | 214.18          | $C^{14}H^{14}O_2$  |
| 15 — naphthazarin, 2 : 3                             | $C^{10}H^4O(OH)_2$  | 190.10          | $C^{10}H^6O_4$     |
| 16 — nitroso acetone                                 | $CH_3.CO.CH:N.OH$   | 87.09           | $C^3H^5O_2N$       |
| 17 — acetophenone                                    | $C^8H^7O_2N$  | 149.10          | $C^8H^7O_2N$       |
| 18 — orcinol, see Dihydroxy toluene                  |   |                 |                    |
| 19 — phloretinic acid                                | $C^9H^{10}O_3$  | 166.13          | $C^9H^{10}O_3$     |
| 20 — quinoline                                       | $C^9H^7N$   | 129.11          | $C^9H^7N$          |
| 21 — vanillin, 1 : 4 : 3                             | $C^8H^7(CHO)(OCH_3)OH$  | 152.10          | $C^8H^8O_3$        |
| 22 Isoprene  | $C^5H^8$  | 68.09           | $C^5H^8$           |
| 23 Itaconic acid                                     | $CH_2:C(COOH)CH_2.COOH$   | 130.07          | $C^5H^6O_4$        |
| 24 Itamalic acid                                     | $CH_2OH.CH(COOH)CH_2.COOH$  | 148.09          | $C^5H^8O_5$        |
| 25 Juglon, see Hydroxy naphthoquinone                |   |                 |                    |
| 26 Kairolin, N. methyl tetra hydroquinoline          | $C^9H_{10}N.CH_3$   | 147.16          | $C^{10}H^{13}N$    |
| 27 Ketazine  | $(CH_3)_2:C:N_2:C:(CH_3)_2$   | 112.15          | $C^6H^{12}N_2$     |
| 28 Keto-butyric acid, propionylformic acid           | $CH_3.CH_2.CO.COOH$   | 102.07          | $C^4H^6O_3$        |

Note:—Many *iso* compounds may

| Density<br>$H_2O=1$ | Solubility in     |           |                 | M.P.<br>°C. | B.P.<br>°C.       |    |
|---------------------|-------------------|-----------|-----------------|-------------|-------------------|----|
|                     | Water.            | Alcohol.  | Ether.          |             |                   |    |
|                     |                   | s.s.      | s.              | 137—138     |                   | 1  |
|                     |                   | s.        | s.              | 190—191     |                   | 2  |
|                     | v.s.s.            | v.s.s.    | v.s.s.          | 236         | subl. d.          | 3  |
|                     | s.                |           |                 |             |                   | 4  |
|                     | i.                | v.s.      | s., s. $C_6H_6$ | 47          | 285—286<br>/219mm | 5  |
| 1.018/0°            | 1:35/19°          |           |                 | 155         | 171.9             | 6  |
| 0.862/20°           |                   |           |                 | - 20 liq    | 171—172           | 7  |
| 1.4708/20°          | 57.11:<br>100/19° | 54:10°    |                 | 92—93       |                   | 8  |
|                     |                   | s.        | s.              |             | 195               | 9  |
| 1.08/16°            | v.s.s.            | s.        | s.              |             | 258—262           | 10 |
|                     |                   |           |                 |             |                   | 11 |
|                     |                   | s.        | s.              | 228         |                   | 12 |
|                     |                   | s.        | i.              |             |                   | 13 |
|                     | s.s.              | v.s.      | v.s.            | 121         |                   | 14 |
|                     | h.s.s.            | s.        | s.              | 276         |                   | 15 |
|                     | v.s.              |           | v.s.            | 65          | subl.             | 16 |
|                     | c.s.s.            |           |                 | 126         |                   | 17 |
|                     |                   |           |                 |             |                   | 18 |
|                     | s.                |           |                 | 128—129     |                   | 19 |
| 1.1025/20°          |                   | s.        |                 | 24.6        | 240/730mm.        | 20 |
| 1.196               | h.s.              | s.        | s.              | 116         | 179/15mm.         | 21 |
| 0.6867/16.5°        |                   |           |                 |             | 34.0/762mm.       | 22 |
| 1.573-1.632         | 1:17/10°          | i:4 (88%) | s.              | 161         | d.                | 23 |
|                     | del.              | s.        | s.              | 64          | d.                | 24 |
|                     |                   |           |                 |             |                   | 25 |
| 1.022/20°           |                   | v.s.      | s.s.            |             | 242—244<br>/720mm | 26 |
| 0.836               |                   |           |                 | 31.5—32     | 131               | 27 |
| 1.2/17°             |                   |           |                 |             | 74—78/<br>25mm.   | 28 |

be found under the corresponding normal compounds.

| Name.                        | Formula.  | Formula Empirical Weight. | Formula.  |
|------------------------------|---|---------------------------|---|
| 1 Keto pyrrolidine           | $\text{CH}_2\text{CO}$<br>$\text{CH}_2\text{CH}_2$<br>$\text{NH}$   | 85.09                     | $\text{C}_4\text{H}_7\text{ON}$                 |
| 2 Kynuric acid, 1:2          | $\text{C}_6\text{H}_4(\text{COOH})\text{NH}\text{CO}\text{COOH}$  | 209.11                    | $\text{C}_8\text{H}_7\text{O}_5\text{N}$        |
| 3 Lactamide                  | $\text{CH}_3\text{CHOH}\text{CONH}_2$   | 89.09                     | $\text{C}_3\text{H}_7\text{O}_2\text{N}$        |
| 4 Lactic acid, <i>d., l.</i> | $\text{CH}_3\text{CHOH}\text{COOH}$   | 90.06                     | $\text{C}_3\text{H}_6\text{O}_3$                |
| 5 —, para, <i>d.</i>         | " "   | 90.06                     | " "   |
| 6 Lactate, ethyl             | $\text{CH}_3\text{CHOH}\text{COOC}_2\text{H}_5$   | 118.11                    | $\text{C}_5\text{H}_{10}\text{O}_3$             |
| 7 Lactic anhydride, $\alpha$ | $\text{CH}_3\text{CHOH}\text{COO}$  | 162.11                    | $\text{C}_6\text{H}_{10}\text{O}_5$             |
| 8 Lactide, $\epsilon$        | $\text{COOH}(\text{CH}_2)\text{CH}$<br>$\text{CH}(\text{CH}_3)\text{CO}$<br>$\text{CO}\text{CH}(\text{CH}_3)$<br>$\text{O}$ | 144.09                    | $\text{C}_6\text{H}_8\text{O}_4$                |
| 9 Lactobionic acid           | $\text{C}_{12}\text{H}_{22}\text{O}_{12}$   | 358.24                    | $\text{C}_{12}\text{H}_{22}\text{O}_{12}$       |
| 10 Lactose, see              | Milk sugar  |                           |   |
| 11 Lactyl urea               | $\text{CO}$<br>$\text{NH}\text{CH}\text{CH}_3$<br>$\text{NH}\text{CO}$  | 132.11                    | $\text{C}_4\text{H}_6\text{O}_2\text{N}_2$      |
| 12 Lævulin                   | $(\text{C}_6\text{H}_{10}\text{O}_5)_x$   | (162.11)                  |   |
| 13 Lævulinic acid            | $\text{CH}_3\text{CO}\text{CH}_2\text{CH}_2\text{COOH}$   | 144.09                    | $\text{C}_5\text{H}_8\text{O}_3$                |
| 14 Lævulose, fructose        | $\text{C}_6\text{H}_{12}\text{O}_6$   | 196.13                    | $\text{C}_6\text{H}_{12}\text{O}_6$             |
| 15 Lauric acid               | $\text{C}_{11}\text{H}_{23}\text{COOH}$   | 200.25                    | $\text{C}_{12}\text{H}_{24}\text{O}_2$          |
| 16 Lead tetraethyl           | $\text{Pb}(\text{C}_2\text{H}_5)_4$   | 324.40                    | $\text{C}_8\text{H}_{20}\text{Pb}$              |
| 17 — tetramethyl             | $\text{Pb}(\text{CH}_3)_4$  | 267.32                    | $\text{C}_4\text{H}_{12}\text{Pb}$              |
| 18 — triethyl                | $\text{Pb}(\text{C}_2\text{H}_5)_3$   | 294.35                    | $\text{C}_6\text{H}_{15}\text{Pb}$              |
| 19 Lecithin                  | $\text{C}_{42}\text{H}_{84}\text{NPO}_9$  | 777.93                    | $\text{C}_{42}\text{H}_{84}\text{O}_9\text{NP}$ |
| 20 Lepidine, 1:3             | $\text{C}_9\text{H}_6\text{N}\text{CH}_3$   | 143.13                    | $\text{C}_{10}\text{H}_9\text{N}$               |
| 21 Leucaniline               | $\text{HC}$<br>$(\text{C}_6\text{H}_4\text{NH}_2)_2$<br>$\text{C}_6\text{H}_3(\text{CH}_3)\text{NH}_2$                      | 303.30                    | $\text{C}_{20}\text{H}_{21}\text{N}_3$          |
| 22 Leucaurine                | $\text{CH}(\text{C}_6\text{H}_5\text{OH})_3$  | 292.22                    | $\text{C}_{19}\text{H}_{16}\text{O}_3$          |
| 23 Leucinic acid             | $\text{C}_5\text{H}_{10}(\text{OH})\text{COOH}$   | 132.13                    | $\text{C}_6\text{H}_{12}\text{O}_3$             |
| 24 Leuconic acid             | $\text{C}_5\text{H}_8\text{O}_9$  | 212.09                    | $\text{C}_5\text{H}_8\text{O}_9$                |
| 25 Lichenine                 | $(\text{C}_6\text{H}_{10}\text{O}_5)_x$   | (162.11)                  |   |
| 26 Lignoceric acid           | $\text{C}_{24}\text{H}_{48}\text{O}_2$  | 368.50                    | $\text{C}_{24}\text{H}_{48}\text{O}_2$          |
| 27 Limonene, <i>d.</i>       | $\text{CH}_3\text{C}$<br>$\text{CH}\text{CH}_2$<br>$\text{CH}_2\text{CH}_2$<br>$\text{CH}\text{C}$<br>$\text{CH}_3$         | 136.18                    | $\text{C}_{10}\text{H}_{16}$                    |
| 28 —                         | " "   | 136.18                    | "   |



| Density<br>H <sub>2</sub> O=1. | Solubility in                                     |               |                      | M.P.<br>°C.              | B.P.<br>°C. |    |
|--------------------------------|---|---------------|----------------------|--------------------------|-------------|----|
|                                | Water.  | Alcohol.      | Ether.               |                          |             |    |
|                                |   |               |                      | 24.6                     | 245         | 1  |
|                                | v.s.s.  | h.s.          | s.s.                 | 257                      |             | 2  |
|                                | v.s.  | s.            | s.                   | 74                       |             | 3  |
| 1.2485/15°                     | del.  | m.            | s.                   | 18                       | 119/12mm.   | 4  |
|                                | m.  | m.            | s.                   | 25—26                    | d.          | 5  |
| 1.055/0                        |   |               |                      | liq.                     | 154.5       | 6  |
|                                | s.s.  | s.            | s.                   | d. 250—260               |             | 7  |
|                                | s.s.  | C.v.s.s.      |                      | 125                      | 255         | 8  |
|                                | v.s.  | s.s.          | i.                   | 100 : lactone            |             | 9  |
|                                |   |               |                      |                          |             | 10 |
|                                | s.  | s.            | s.s.                 | 145                      |             | 11 |
|                                | s.  | v.s.s. (abs.) | i.                   | d.                       |             | 12 |
| 1.1395/20°                     | m.  | s.            | s.                   | 32.5—33                  | 250—253     | 13 |
|                                | s.  | s.            | s.                   | 95                       | d. 100      | 14 |
| 0.883/20°                      | i.  | s.            | s.                   | 43.6                     | 225/100     | 15 |
| 1.62                           | i.  |               |                      | liq.                     | 152         | 16 |
| 2.034/0°                       |   |               |                      | liq.                     | 110         | 17 |
| 1.471/10°                      | i.  |               |                      | liq.                     | d.          | 18 |
|                                | i.  | s.            | s.                   | d.                       |             | 19 |
| 1.0862/20°                     | s.s.  | m.            | m.                   | liq.                     | 265.5/746.7 | 20 |
|                                | h.s.s.  | v.s.          | s.s.                 | 100                      |             | 21 |
|                                | s.s.  | s.            | s. acetic.           |                          |             | 22 |
|                                | s.  | s.            | s.                   | 76—77 rac.<br>81—82 act. |             | 23 |
|                                | v.s.  | s.s.          | v.s.s.               |                          |             | 24 |
|                                | h.s.  | i.            | i.                   |                          |             | 25 |
|                                | s.CS <sub>2</sub> , C <sub>6</sub> H <sub>6</sub> | s.            | s.                   | 80—81                    |             | 26 |
| 0.853/10°                      |   |               | s. CHCl <sub>3</sub> |                          | 177.6—178   | 27 |
| 0.846/20°                      |   | s.            | s. CHCl <sub>3</sub> |                          | 175—176     | 28 |

| Name.                     | Formula.  | Formula Weight. | Empirical Formula.                          |
|---------------------------|---|-----------------|---|
| 1 Linalool                | $(\text{CH}_3)_2 : \text{C} : \text{CH} . (\text{CH}_2)_2 .$<br>$\text{C}(\text{OH}_3) . \text{OH} . \text{CH} : \text{CH}_2$                                     | 154.19          | $\text{C}_{10}\text{H}_{18}\text{O}$        |
| 2 Linoleic acid           | $\text{C}_{18}\text{H}_{32}\text{O}_2$  | 280.35          | $\text{C}_{18}\text{H}_{32}\text{O}_2$      |
| 3 Lophine                 | $\text{C}_{21}\text{H}_{16}\text{N}_2$  | 298.27          | $\text{C}_{21}\text{H}_{16}\text{N}_2$      |
| 4 Luteolin                | $(\text{OH})_2 \begin{cases} \text{O} . \text{C} . \text{C}_6\text{H}_3(\text{OH})_2 \\ \parallel \\ \text{CO} . \text{CH} \end{cases}$<br>$\text{C}_6\text{H}_2$ | 286.16          | $\text{C}_{15}\text{H}_{10}\text{O}_6$      |
| 5 Lutidine, 2:6           | $\text{C}_5\text{H}_3\text{N}(\text{CH}_3)_2$   | 107.12          | $\text{C}_7\text{H}_9\text{N}$              |
| 6 Lutidic acid, see       | Pyridine dicarboxylic acid  |                 |   |
| 7 Lysine, see             | Amino caproic acid  |                 |   |
| 8 Maclurin                | $\text{CO} \begin{cases} \text{C}_6\text{H}_2(\text{OH})_3 \\ \text{C}_6\text{H}_4(\text{OH})_2 \end{cases}$  | 280.17          | $\text{C}_{13}\text{H}_{10}\text{O}_6$      |
| 9 Maleic acid             | $\text{C}_2\text{H}_2(\text{COOH})_2$   | 116.05          | $\text{C}_4\text{H}_2\text{O}_4$            |
| 10 — anhydride            | $\text{C}_2\text{H}_2 : (\text{CO})_2 : \text{O}$   | 98.04           | $\text{C}_4\text{H}_2\text{O}_4$            |
| 11 Malic acid, l          | $\text{COOH} . \text{CHOH} . \text{CH}_2 . \text{COOH}$   | 134.07          | $\text{C}_4\text{H}_6\text{O}_5$            |
| 12 Malic amide            | $\text{C}_2\text{H}_3(\text{OH})(\text{CO} . \text{NH}_2)_2$  | 132.10          | $\text{C}_4\text{H}_6\text{O}_5\text{N}_2$  |
| 13 Malate, ethyl          | $\text{CH}_2 . \text{COOC} . \text{C}_2\text{H}_5$  | 190.15          | $\text{C}_8\text{H}_{14}\text{O}_5$         |
| 14 Malonic acid           | $\text{CHOH} . \text{COOC} . \text{C}_2\text{H}_5$<br>$\text{CH}_2(\text{COOH})_2$  | 104.05          | $\text{C}_3\text{H}_4\text{O}_4$            |
| 15 Malonate, diethyl      | $\text{CH}_2(\text{COOC} . \text{C}_2\text{H}_5)_2$   | 160.13          | $\text{C}_7\text{H}_{12}\text{O}_4$         |
| 16 Malonyl chloride       | $\text{CH}_2 : (\text{COCl})_2$   | 152.95          | $\text{C}_3\text{H}_2\text{O}_2\text{Cl}_2$ |
| 17 — urea                 | $\text{CO} : (\text{NH} . \text{CO})_2 : \text{CH}_2$   | 128.09          | $\text{C}_3\text{H}_4\text{O}_2\text{N}_2$  |
| 18 Maltose                | $\text{C}_{12}\text{H}_{22}\text{O}_{11} . \text{H}_2\text{O}$  | 360.26          | $\text{C}_{12}\text{H}_{22}\text{O}_{11}$   |
| 19 Mandelic acid          | $\text{C}_6\text{H}_5 . \text{CHOH} . \text{COOH}$  | 152.10          | $\text{C}_8\text{H}_8\text{O}_3$            |
| 20 Mannitan, amorph       | $\text{C}_6\text{H}_{12}\text{O}_5$   | 164.13          | $\text{C}_6\text{H}_{12}\text{O}_5$         |
| 21 —, cryst               | "   | 164.13          | "   |
| 22 Mannitol, d            | $\text{C}_6\text{H}_8(\text{OH})_6$   | 182.14          | $\text{C}_6\text{H}_{14}\text{O}_6$         |
| 23 — nitrate              | $\text{C}_6\text{H}_8(\text{ONO})_2$  | 452.15          | $\text{C}_6\text{H}_8\text{O}_6\text{N}_2$  |
| 24 Manno-heptose d        | $\text{C}_6\text{H}_7(\text{OH})_6\text{CHO}$   | 210.15          | $\text{C}_7\text{H}_{14}\text{O}_7$         |
| 25 — octite, d            | $\text{C}_8\text{H}_{18}\text{O}_8$   | 242.18          | $\text{C}_8\text{H}_{18}\text{O}_8$         |
| 26 Mannonic acid, d, l, i | $\text{C}_5\text{H}_6(\text{OH})_5\text{COOH}$  | 196.13          | $\text{C}_6\text{H}_{12}\text{O}_7$         |
| 27 — lactone, d           | $\text{C}_5\text{H}_{10}\text{O}_6$   | 178.11          | $\text{C}_5\text{H}_{10}\text{O}_6$         |
| 28 Mannose, d. (Seminose) | $\text{C}_6\text{H}_{12}\text{O}_6$   | 180.13          | $\text{C}_6\text{H}_{12}\text{O}_6$         |
| 29 Margaric acid          | $\text{C}_{18}\text{H}_{33}\text{COOH}$   | 270.36          | $\text{C}_{17}\text{H}_{34}\text{O}_2$      |
| 30 Meconic acid           | $\text{C}_7\text{H}_4\text{O}_7 . 3\text{H}_2\text{O}$  | 254.12          | $\text{C}_7\text{H}_4\text{O}_7$            |
| 31 Meconine               | $\text{C}_{10}\text{H}_{10}\text{O}_4$  | 194.13          | $\text{C}_{10}\text{H}_{10}\text{O}_4$      |
| 32 Melam                  | $\text{C}_6\text{H}_9\text{N}_{11}$   | 235.21          | $\text{C}_6\text{H}_9\text{N}_{11}$         |

| Density,<br>H <sub>2</sub> O=1. | Solubility in |             |        | M.P.<br>°C.   | B.P.<br>°C. |    |
|---------------------------------|---------------|-------------|--------|---------------|-------------|----|
|                                 | Water.        | Alcohol.    | Ether. |               |             |    |
| 0.870/15°                       |               |             |        | liq.          | 199—200     | 1  |
| 0.9206/14°                      |               |             |        | oil.          |             | 2  |
|                                 | i.            | s.s.        | s.s.   | 270           |             | 3  |
|                                 | v.s.s.        | 1:37        | s.s.   | 328—329.5     |             | 4  |
| 0.946/0°                        | 1:3.5         |             |        | liq.          | 142—143     | 5  |
|                                 |               |             |        |               |             | 6  |
|                                 |               |             |        |               |             | 7  |
|                                 | h.s.          | s.          | s.     | 200           |             | 8  |
| 1.590                           | 1:2/10°       | s.          | s.     | 130—130.5     | d.          | 9  |
| 0.9339/19.2°                    |               |             |        | 50—51         | 196         | 10 |
| 1.559/4°                        | v.s.          | v.s.        |        | 100           | d.          | 11 |
|                                 | 1:12/8°       | i.          |        | 170           |             | 12 |
| 1.1210/21°                      |               |             |        | liq.          | 149—25mm.   | 13 |
| 1.061/15°                       | v.s.          | s.          | s.     | 132           | d.          | 14 |
|                                 |               |             |        | —49.9         | 198—198.6   | 15 |
|                                 |               |             |        |               | 47/13mm.    | 16 |
|                                 | h.s.          |             |        | d.            |             | 17 |
| 1.540/17.5°                     | s.            | s.s.        |        |               |             | 18 |
| 1.36/4°                         | 15.97:        | s.          | s.     | inact. 118.5. |             | 19 |
|                                 | 100/20°       |             |        | l. 133        |             |    |
|                                 | s.            | v.s. (abs.) | i.     | 100           |             | 20 |
| 1.521                           | 1:4/15°       | s.s.        |        |               |             | 21 |
|                                 | 27:100/25°    | h.s.        | i.     | 165           | 278/1mm     | 22 |
| 1.604                           | i.            | h.s.        | s.     | 108           | expl.       | 23 |
|                                 | s.            | s.s.        |        | 134—135       |             | 24 |
|                                 | h.s.s.        |             |        | 258           |             | 25 |
|                                 | s.            |             |        | FORMS LACTONE |             | 26 |
|                                 |               |             |        | 149—153       |             | 27 |
|                                 | 248:100/17°   | v.s.s. abs. | i.     | 123           |             | 28 |
|                                 |               |             |        | 59.5          | 227/100     | 29 |
|                                 | s.            | s.          | s.     |               |             | 30 |
|                                 | 1:22/100°     |             |        | 102           | subl.       | 31 |
|                                 | i.            | s.h. KOH.   |        |               |             | 32 |

| Name.                              | Formula.  | Formula Empirical | Weight. | Formula.          |
|------------------------------------|---|-------------------|---------|-------------------|
| 1 Melene                           | $C_{30}H_{60}$  | $C_{30}H_{60}$    | 420.63  | $C_{30}H_{60}$    |
| 2 Melilotic acid                   | $C_6H_4(OH)CH_2 \cdot CH_2 \cdot COOH$  | $C_9H_{10}O_3$    | 166.13  | $C_9H_{10}O_3$    |
| 3 Melissic acid                    | $C_{29}H_{58}COOH$  | $C_{30}H_{60}O_2$ | 452.63  | $C_{30}H_{60}O_2$ |
| 4 Melissyl alcohol                 | $C_{30}H_{61}OH$  | $C_{30}H_{62}O$   | 438.65  | $C_{30}H_{62}O$   |
| 5 Melitriose, see                  | Raffinose   |                   |         |                   |
| 6 Mellitic acid                    | $C_6(COOH)_4$   | $C_{12}H_6O_{12}$ | 342.11  | $C_{12}H_6O_{12}$ |
| 7 Mellophanic acid                 | $C_6H_2(COOH)_4 (1:2:3:5)$  | $C_{10}H_6O_8$    | 254.10  | $C_{10}H_6O_8$    |
| 8 Menthene                         | $C_{10}H_{18}$  | $C_{10}H_{18}$    | 138.19  | $C_{10}H_{18}$    |
| 9 Menthol, <i>d</i>                | $C_{10}H_{19}(OH)$  | $C_{10}H_{20}O$   | 156.20  | $C_{10}H_{20}O$   |
| 10 Menthone, <i>d</i>              | $C_{10}H_{18}O$   | $C_{10}H_{18}O$   | 154.19  | $C_{10}H_{18}O$   |
| 11 Mercury di-ethyl                | $Hg(C_2H_5)_2$  | $C_4H_{10}Hg$     | 258.70  | $C_4H_{10}Hg$     |
| 12 — dimethyl                      | $Hg(CH_3)_2$  | $C_2H_6Hg$        | 230.66  | $C_2H_6Hg$        |
| 13 — dinaphthyl, 1                 | $Hg(C_{10}H_7)_2$   | $C_{20}H_{14}Hg$  | 454.81  | $C_{20}H_{14}Hg$  |
| 14 — —, 2                          | "   | "                 | 454.81  | "                 |
| 15 — diphenyl                      | $Hg(C_6H_5)_2$  | $C_{12}H_{10}Hg$  | 354.74  | $C_{12}H_{10}Hg$  |
| 16 — mercaptan                     | $Hg_2(C_2H_5)_2S$   | $C_4H_{10}SHg_2$  | 491.96  | $C_4H_{10}SHg_2$  |
| 17 Mesaconic acid                  | $(CH_3)_2(COOH)C:CH \cdot COOH$   | $C_5H_6O_4$       | 130.07  | $C_5H_6O_4$       |
| 18 Mesidine, 1:3:5:2               | $C_6H_2(CH_3)_3NH_2$  | $C_9H_{13}N$      | 135.16  | $C_9H_{13}N$      |
| 19 Mesitol                         | $C_6H_3(CH_3)_3OH$  | $C_9H_{12}O$      | 136.14  | $C_9H_{12}O$      |
| 20 Mesitylene, 1:3:5               | $C_6H_3(CH_3)_3$  | $C_9H_{12}$       | 120.14  | $C_9H_{12}$       |
| 21 Mesitylenic acid                | $C_6H_3(CH_3)_3COOH$  | $C_9H_{10}O_2$    | 150.13  | $C_9H_{10}O_2$    |
| 22 Mesityl oxide                   | $(CH_3)_2:C:CH \cdot COCH_3$  | $C_8H_{10}O$      | 98.11   | $C_8H_{10}O$      |
| 23 Mesorcin                        | $C_6H(CH_3)_3(OH)_2$  | $C_9H_{12}O_2$    | 152.14  | $C_9H_{12}O_2$    |
| 24 Mesoxalic acid                  | $(COOH)_2C(OH)_2$   | $C_3H_4O_6$       | 136.05  | $C_3H_4O_6$       |
| 25 Metacetone                      | $C_6H_{10}O$  | $C_6H_{10}O$      | 98.11   | $C_6H_{10}O$      |
| 26 Metacrolein                     | $C_9H_{12}O$  | $C_9H_{12}O$      | 136.14  | $C_9H_{12}O$      |
| 27 Metaldehyde                     | $(CH_3CHO)_3$   | $C_6H_{12}O_3$    | 132.12  | $C_6H_{12}O_3$    |
| 28 Metanilic acid, see             | Amino benzene sulphonic acid  |                   |         |                   |
| 29 Metastyroline                   | $(C_8H_8)_x$  | (104.10)          |         |                   |
| 30 Methacrylic acid                | $CH_2:C:(CH_3)COOH$   | $C_4H_6O_2$       | 86.07   | $C_4H_6O_2$       |
| 31 Methane                         | $CH_4$  | $CH_4$            | 16.04   | $CH_4$            |
| 32 Methoxy pyridine, $\gamma$      | $C_2H_2 \begin{array}{c} \diagup C \diagdown \\ \diagdown N \diagup \end{array} \begin{array}{c} -OCH_3 \\ \\ \end{array} C_2H_2$ | $C_6H_7ON$        | 109.10  | $C_6H_7ON$        |
| 33 — quinoline, $\gamma$           | $C_9H_6N(OCH_3)$  | $C_{10}H_9ON$     | 159.13  | $C_{10}H_9ON$     |
| 34 Methyl acetanilide              | $C_6H_5 \cdot N(CH_3) \cdot CO \cdot CH_3$  | $C_9H_{11}ON$     | 149.14  | $C_9H_{11}ON$     |
| 35 — acetoacetic acid, ethyl ester | $CH_3CO \cdot CH(CH_3)COOC_2H_5$  | $C_7H_{12}O_3$    | 144.13  | $C_7H_{12}O_3$    |

| Density<br>$H_2O=1$ . | Solubility in |            |                           | M.P.<br>°C.  | B.P.<br>°C. |    |
|-----------------------|---------------|------------|---------------------------|--------------|-------------|----|
|                       | Water.        | Alcohol.   | Ether.                    |              |             |    |
| 1.89                  |               | 3.6:100 h. |                           | 62           |             | 1  |
|                       | 1: 20/18°     | s.         | s.                        | 82—83        | d.          | 2  |
|                       |               | h.s.       | s.s.                      | 90           |             | 3  |
|                       |               |            |                           | 88           |             | 4  |
|                       |               |            |                           |              |             | 5  |
|                       | v.s.          | s.         |                           | 286—288      |             | 6  |
|                       |               |            |                           | under press. |             |    |
|                       | s.            |            |                           | 238          |             | 7  |
| 0.837/0°              |               |            |                           | 167.4        |             | 8  |
| 0.890/15°             | s.s.          | s.         | s.                        | 42           | 212         | 9  |
| 0.9126/0°             | m. $CHCl_3$   | m.         | m. $C_6H_6$               | liq.         | 206-208     | 10 |
| 2.44                  | i.            | s.s.       | s.                        | liq.         | 159         | 11 |
| 3.069                 | i.            |            |                           | liq.         | 96          | 12 |
| 1.929                 | $S.CS_2$      | h.s.s      | s. $CHCl_3$               | 243          |             | 13 |
|                       |               |            |                           | 238          |             | 14 |
| 2.32                  | $S.CS_2$      | h.s.s      | s. $CHCl_3$ ,<br>$C_6H_6$ | 120          | 300 d.      | 15 |
|                       |               |            |                           | 82           | d.          | 16 |
|                       | 2.7: 100/18°  | s.         |                           | 202          | d.          | 17 |
| 0.9633                |               |            |                           | liq.         | 227         | 18 |
|                       |               | s.         | s.                        | 68—69        | 219.5       | 19 |
| 0.8694/10°            | i.            | s.         | s.                        | — 57.5       | 164.5       | 20 |
|                       | h.s.s.        | v.s.       |                           | 165—166      | subl.       | 21 |
| 0.8578/20°            | i.            | m.         |                           | liq.         | 131—132     | 22 |
|                       | c.s.s.        | v.s.       | v.s.                      | 149—150      | 275         | 23 |
|                       | s.            | s.         | s.                        | 115          |             | 24 |
| > $H_2O$              | i.            |            |                           |              | 84          | 25 |
|                       | h.v.s.s.      | s.         | s.                        | 50           | 170         | 26 |
|                       | i.            | s.s.       | s.s.                      | 246.2        |             | 27 |
|                       |               |            |                           |              |             | 28 |
| 1.054/13°             | i.            | i.         | v.s.s.                    |              | 320 d.      | 29 |
| 1.0153/20°            | v.s.          |            |                           | 16           | 160.5       | 30 |
|                       | 0.054: 1 vol. |            |                           | — 184        | — 164       | 31 |
|                       |               |            |                           |              |             |    |
|                       | s.            |            |                           | liq.         | 191—738mm   | 32 |
| 1.665/0°              |               | s.         |                           | 31           | 241         | 33 |
|                       | i.            | s.         |                           | 101          | 237         | 34 |
| 1.009/6°              |               |            |                           |              | 189.7       | 35 |

| Name.                                   | Formula.   | Formula Weight. | Empirical Formula.                       |
|---|--|-----------------|--|
| 1 Methyl acetoacetic acid, methyl ester | $\text{CH}_3\text{CO}.\text{CH}(\text{CH}_3)\text{COOCH}_3$  | 130.11          | $\text{C}_6\text{H}_{10}\text{O}_3$      |
| 2 — acetophenone, <i>o</i>              | $\text{CH}_3.\text{C}_6\text{H}_4.\text{COCH}_3$   | 134.12          | $\text{C}_9\text{H}_{10}\text{O}$        |
| 3 —, <i>m</i>                           | " "  | 134.12          | "  |
| 4 —, <i>p</i>                           | " "  | 134.12          | "  |
| 5 — acridine, 1                         | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{C} \diagdown \\   \\ \text{N} \end{array} \begin{array}{c} -\text{CH}_3 \\ \diagup \text{C}_6\text{H}_4 \diagdown \end{array}$  | 193.17          | $\text{C}_{14}\text{H}_{11}\text{N}$     |
| 6 —, 3                                  | $\text{C}_{13}\text{H}_8\text{N}.\text{CH}_3$  | 193.17          | "  |
| 7 —, 5                                  | " "  | 193.17          | "  |
| 8 — alcohol                             | $\text{CH}.\text{OH}$  | 32.04           | $\text{CH}_2\text{O}$                    |
| 9 — alizarin                            | $\text{C}_6\text{H}_4 : (\text{CO})_2 : \text{C}_6\text{H}(\text{CH}_3)(\text{OH})_2$  | 254.16          | $\text{C}_{15}\text{H}_{10}\text{O}_4$   |
| 10 — amine                              | $\text{CH}_3.\text{NH}_2$  | 31.06           | $\text{CH}_5\text{N}$                    |
| 11 — amino acetic acid                  | $\text{CH}_3(\text{NH}.\text{CH}_2)\text{COOH}$  | 89.09           | $\text{C}_3\text{H}_7\text{O}_2\text{N}$ |
| 12 — aniline                            | $\text{C}_6\text{H}_5.\text{NH}.\text{CH}_3$   | 107.12          | $\text{C}_7\text{H}_9\text{N}$           |
| 13 — anthracene, 1                      | $\text{C}_6\text{H}_4 : (\text{CH})_2 : \text{C}_6\text{H}_3.\text{CH}_3$  | 192.17          | $\text{C}_{15}\text{H}_{12}$             |
| 14 —, 2                                 | " "  | 192.17          | "  |
| 15 — anthraquinone, 1                   | $\text{C}_{14}\text{H}_7\text{O}_2.\text{CH}_3$  | 222.16          | $\text{C}_{15}\text{H}_{10}\text{O}_2$   |
| 16 —, 2                                 | " "  | 222.16          | "  |
| 17 — arsenic acid                       | $\text{CH}_3.\text{HASO}_2(\text{OH})$   | 140.01          | $\text{CH}_5\text{O}_3\text{As}$         |
| 18 — oxide                              | $\text{AsO}.\text{CH}_3$   | 105.99          | $\text{CH}_3\text{OAs}$                  |
| 19 — dichloride                         | $\text{AsCl}_2.\text{CH}_3$  | 160.91          | $\text{CH}_3\text{Cl}_2\text{As}$        |
| 20 — benzothiazole                      | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{N} \diagdown \\   \\ \text{S} \end{array} \begin{array}{c} \diagup \text{C} \diagdown \\   \\ \text{O} \end{array} \text{CH}_3$ | 149.16          | $\text{C}_8\text{H}_7\text{NS}$          |
| 21 — benzoxazole                        | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{N} \diagdown \\   \\ \text{O} \end{array} \begin{array}{c} \diagup \text{C} \diagdown \\   \\ \text{O} \end{array} \text{CH}_3$ | 133.10          | $\text{C}_8\text{H}_7\text{ON}$          |
| 22 — borate                             | $(\text{CH}_3)_3\text{BO}_3$   | 104.0           | $\text{C}_3\text{H}_9\text{O}_3\text{B}$ |
| 23 — bromide                            | $\text{CH}_3.\text{Br}$  | 94.95           | $\text{CH}_3\text{Br}$                   |
| 24 — carbylamine                        | $\text{CH}_3.\text{NC}$  | 41.04           | $\text{C}_2\text{H}_3\text{N}$           |
| 25 — chloride                           | $\text{CH}_3.\text{Cl}$  | 50.49           | $\text{CH}_3\text{Cl}$                   |
| 26 — chloroform                         | $\text{CCl}_3.\text{CH}_3$   | 133.41          | $\text{C}_2\text{H}_3\text{Cl}_3$        |
| 27 — coumarin, $\alpha$                 | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{C}(\text{CH}_3) \diagdown \\   \\ \text{O}-\text{CO} \end{array}$   | 160.11          | $\text{C}_{10}\text{H}_8\text{O}_2$      |
| 28 —, $\beta$                           | $\text{C}_9\text{H}_5\text{O}_2.\text{CH}_3$   | 160.11          | "  |
| 29 — cyanate                            | $\text{N} : \text{C}.\text{OCH}_3$   | 57.04           | $\text{C}_2\text{H}_3\text{ON}$          |
| 30 —, iso                               | $\text{CO} : \text{N}.\text{CH}_3$   | 57.04           | "  |

| Density<br>$H_2O=1$ . | Solubility in |          |             | M.P.<br>°C. | B.P.<br>°C.          |    |
|-----------------------|---------------|----------|-------------|-------------|----------------------|----|
|                       | Water.        | Alcohol. | Ether.      |             |                      |    |
|                       |               |          |             |             | 63.8—64/11mm.        | 1  |
| 0.026/20°             |               |          |             |             | 211/745mm. (corr.)   | 2  |
| 0.986/20°             |               |          |             |             | 221/745mm. (corr.)   | 3  |
| 1.021/0°              |               | m.       | m.          |             | 224.5/745mm. (corr.) | 4  |
|                       | s. $C_6H_6$   | v.s.     | v.s.        | 88          |                      | 5  |
|                       |               |          |             | 125—126     |                      | 6  |
|                       |               |          |             | 114         |                      | 7  |
| 0.8102/0°             | m.            | m.       | m.          | - 97.8      | 64.7                 | 8  |
|                       | s. acetone    | s.       | s.          | 232—233     | subl. 200            | 9  |
|                       |               | s.       |             |             |                      |    |
| 0.699/—11°            | 1150 : 1 vol. |          |             | gas.        | - 6.7/75mm           | 10 |
|                       | v.s.          | s.s.     |             | 130         | 250 d.               | 11 |
| 0.9863/20°            |               |          |             | - 80        | 193.8                | 12 |
|                       | s. $CS_2$     | s.       | s. $C_6H_6$ | 85—86       |                      | 13 |
|                       |               |          |             | 199—200     |                      | 14 |
|                       |               | s.       | s.          | 161—163     | subl.                | 15 |
|                       |               |          |             | 177         |                      | 16 |
|                       | s.            | s.       |             | 161         |                      | 17 |
|                       |               |          |             | 95          | 3.                   | 18 |
|                       |               |          |             | liq.        | 133                  | 19 |
|                       | i.            | s.       |             | liq.        | 238                  | 20 |
|                       | i.            | s.       |             | liq.        | 201                  | 21 |
| 0.94/0°               |               |          |             |             | 65—66                | 22 |
| 1.732/0°              | s.s.          | s.       |             |             | 4.5                  | 23 |
| 0.7557                | 1 : 10        | 35 : 1   |             | - 45        | 59.6                 | 24 |
| 0.9915/—24°           | s.s.          | s.       | s. acetic.  | - 103.6     | - 24.1               | 25 |
| 1.3657                |               |          |             |             | 74                   | 26 |
|                       |               | s.       | s. $C_6H_6$ | 90          |                      | 27 |
|                       |               |          |             | 81—82       |                      | 28 |
|                       | h.s.          | s.       |             |             |                      | 29 |
|                       | i.            | s.       |             |             | 45                   | 30 |

| Name.                         | Formula.   | Formula Weight. | Empirical Formula.                         |
|-------------------------------|--|-----------------|--|
| 1 Methyl cyanide              | $\text{CH}_3\text{CN}$   | 41.04           | $\text{C}_2\text{H}_3\text{N}$             |
| 2 — cyclo hexane, see         | Hexa hydro toluene   |                 |  |
| 3 — diphenylamine             | $(\text{C}_6\text{H}_5)_2:\text{N}.\text{CH}_3$                    | 183.18          | $\text{C}_{13}\text{H}_{13}\text{N}$       |
| 4 — ether                     | $\text{CH}_3.\text{O}.\text{CH}_3$                                 | 46.06           | $\text{C}_2\text{H}_6\text{O}$             |
| 5 — furfurane, sylvan         | $\text{C}_4\text{H}_4\text{O}.\text{CH}_3$                         | 82.07           | $\text{C}_5\text{H}_6\text{O}$             |
| 6 — furfurol, 5:2             | $\text{C}_5\text{H}_4\text{O}_2.\text{CH}_3$                       | 110.08          | $\text{C}_6\text{H}_6\text{O}_2$           |
| 7 — glycocyamide, see         | Creatine   |                 |  |
| 8 — glycocyamidine, see       | Creatinine   |                 |  |
| 9 — glyoxalin                 | $\text{C}_3\text{H}_3\text{N}_2.\text{CH}$                         | 82.09           | $\text{C}_4\text{H}_4\text{N}_2$           |
| 10 — guaiacol                 | $\text{C}_6\text{H}_3(\text{OH})(\text{OCH}_3)\text{CH}_3$         | 138.12          | $\text{C}_8\text{H}_{10}\text{O}_2$        |
| 11 — hydantoin, 1:2:4         | $\text{C}_4\text{H}_6\text{N}_2\text{O}$                           | 114.09          | $\text{C}_4\text{H}_6\text{O}_2\text{N}_2$ |
| 12 — hydrazine                | $\text{CH}_3.\text{NH}.\text{NH}_2$                                | 46.07           | $\text{CH}_6\text{N}_2$                    |
| 13 — hydroxylamine, $\beta$   | $\text{CH}_3.\text{NH}.\text{OH}$                                  | 47.06           | $\text{CH}_6\text{ON}$                     |
| 14 — indole, N                | $\text{C}_8\text{H}_6\text{N}.\text{CH}_3$                         | 131.12          | $\text{C}_9\text{H}_9\text{N}$             |
| 15 —, $\alpha$                | $\text{CH}_3.\text{C}_8\text{H}_5\text{NH}$                        | 131.12          | "  |
| 16 —, $\beta$                 | " "  | 131.12          | "  |
| 17 — iodide                   | $\text{CH}_3\text{I}$  | 141.05          | $\text{CH}_3\text{I}$                      |
| 18 — isatin                   | $\text{C}_8\text{H}_4\text{O}_2\text{N}(\text{CH}_3)$              | 161.11          | $\text{C}_9\text{H}_7\text{O}_2\text{N}$   |
| 19 —, pseudo                  | $\text{C}_8\text{H}_4\text{ON}(\text{OCH}_3)$                      | 161.11          | "  |
| 20 — mercaptan                | $\text{CH}_3.\text{SH}$  | 48.10           | $\text{CH}_3\text{S}$                      |
| 21 — naphthalene, 1           | $\text{C}_{10}\text{H}_7.\text{CH}_3$                              | 142.14          | $\text{C}_{11}\text{H}_{10}$               |
| 22 —, 2                       | " "  | 142.14          | "  |
| 23 — naphthylamine, 1         | $\text{C}_{10}\text{H}_7.\text{NH}.\text{CH}_3$                    | 157.15          | $\text{C}_{11}\text{H}_{11}\text{N}$       |
| 24 — naphthyl ether, $\alpha$ | $\text{C}_{10}\text{H}_7.\text{O}.\text{CH}_3$                     | 158.14          | $\text{C}_{11}\text{H}_{10}\text{O}$       |
| 25 —, $\beta$                 | " "  | 158.14          | "  |
| 26 — nitrate                  | $\text{CH}_3.\text{NO}_3$  | 77.04           | $\text{CH}_3\text{O}_3\text{N}$            |
| 27 — nitrite                  | $\text{CH}_3.\text{NO}_2$  | 61.04           | $\text{CH}_3\text{O}_2\text{N}$            |
| 28 — nitrolic acid            | $\text{CH}(\text{NO}_2)\text{NOH}$                                 | 90.04           | $\text{CH}_2\text{O}_2\text{N}_2$          |
| 29 — nonyl ketone             | $\text{CH}_3.\text{CO}.\text{C}_9\text{H}_{19}$                    | 170.23          | $\text{C}_{11}\text{H}_{22}\text{O}$       |
| 30 — phenazine                | $\text{C}_6\text{H}_4:\text{N}_2:\text{C}_6\text{H}_3.\text{CH}_3$ | 194.17          | $\text{C}_{13}\text{H}_{10}\text{N}_2$     |
| 31 — phosphate                | $\text{CH}_3.\text{PO}_2(\text{OH})_2$                             | 112.09          | $\text{CH}_5\text{O}_4\text{P}$            |
| 32 — phosphine                | $\text{CH}_3.\text{PH}_2$  | 48.09           | $\text{CH}_5\text{P}$                      |
| 33 — piperidine, see          | Pipecoline   |                 |  |
| 34 — propyl benzene, o        | $\text{CH}_3.\text{C}_6\text{H}_4.\text{C}_3\text{H}_7$            | 134.16          | $\text{C}_{10}\text{H}_{14}$               |
| 35 —, m                       | " "  | 134.16          | "  |
| 36 —, p                       | " "  | 134.16          | "  |



| Density<br>$H_2O=1$ . | Solubility in           |          |                      | M.P.<br>°C. | B.P.<br>°C.   |    |
|-----------------------|-------------------------|----------|----------------------|-------------|---------------|----|
|                       | Water                   | Alcohol. | Ether.               |             |               |    |
| 1.8052/0°             | m.                      | s.       | s.                   | -44.4       | 81.6          | 1  |
|                       |                         |          |                      |             |               | 2  |
| 0.476/2/0°            | s.                      |          |                      | liq.        | 282           | 3  |
|                       | 37 : 1 vol.             | s.       | 600 : 1<br>$H_2SO_4$ | - 138.4     | - 23.7        | 4  |
| 0.887                 |                         |          |                      |             | 63—63.5       | 5  |
| 1.087/18°             | 1 : 30                  | s.       |                      |             | 184—186       | 6  |
|                       |                         |          |                      |             |               | 7  |
|                       |                         |          |                      |             |               | 8  |
| 1.036/10°             | s.                      |          |                      | - 6         | 197—199       | 9  |
| 1.1534/0°             | 1 : 60/15°<br>by vol.   | m.       | m.                   | liq.        | 219           | 10 |
|                       | s.                      | s.       |                      | 156         | subl.         | 11 |
|                       |                         | m.       | m.                   |             | 87/745mm.     | 12 |
|                       | v.s.                    | v.s.     |                      | 42          | 62.5/15mm.    | 13 |
| 1.0707/0°             | i.                      | s.       | s.                   |             | 240—241/720mm | 14 |
|                       | h.s.                    | v.s.s.   | v.s.s.               | 59          | 272/750mm.    | 15 |
|                       | s.s.                    | s.       | i.                   | 95          | 265—266/755mm | 16 |
| 2.2852/15°            | 1 : 125/<br>15° by vol. | s.       |                      | - 64.4      | 42.3          | 17 |
|                       | c.s.s.                  | s. alk.  | s. h. HCl            | 184         |               | 18 |
|                       | s.s.                    |          |                      | 134         |               | 19 |
| < $H_2O$              | d.                      | s.       | s.                   | liq.        | 5.8/752mm     | 20 |
| 1.0287/12°            |                         | s.       | s.                   | liq.        | 240—242       | 21 |
|                       |                         | s.s.     |                      | 32.5        | 243—245       | 22 |
|                       | s. $CS_2$               | s.       | s.                   |             | 290—293       | 23 |
| 1.0974/15°            |                         |          |                      | liq.        | 265           | 24 |
|                       | s.s.                    | s.s.     | v.s.                 | 75          | 271           | 25 |
| 1.2322/5°             | s.s.                    |          |                      | liq.        | 65 expl.      | 26 |
| 0.991/15°             |                         |          |                      | gas.        | - 12          | 27 |
|                       | s.                      |          | s.                   | 64          |               | 28 |
| 0.8295/17.5°          |                         |          |                      | 15          | 232           | 29 |
|                       | h.s.s.                  | s.s.     | v.s.                 | 117         | d. 350        | 30 |
|                       |                         |          |                      | 105         |               | 31 |
|                       | s.s.                    | v.s.     | 70 : 1 vol.          | gas         | - 14/758.5    | 32 |
|                       |                         |          |                      |             |               | 33 |
|                       | i.                      | s.       |                      | liq.        | 181—182       | 34 |
| 0.863/16°             | i.                      | s.       |                      | liq.        | 176—177.5     | 35 |
| 0.8682/0°             | i.                      | s.       |                      |             | 183—184       | 36 |

| Name.  | Formula.   | Formula Empirical Weight. | Empirical Formula.                         |
|--|--|---------------------------|--|
| 1 Methyl <i>iso</i> propyl benzene, <i>m</i>             | $\text{CH}_3 \cdot \text{C}_6\text{H}_4 \cdot \text{CH} : (\text{CH}_3)_2$   | 134.16                    | $\text{C}_{10}\text{H}_{14}$               |
| 2 — — —, <i>p</i>  | " "  | 134.16                    | "  |
| 3 — propyl ketone  | $\text{CH}_3 \cdot \text{CO} \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{CH}_3$  | 86.10                     | $\text{C}_5\text{H}_{10}\text{O}$          |
| 4 — <i>iso</i> propyl ketone                             | $\text{CH}_3 \cdot \text{CO} \cdot \text{CH}(\text{CH}_3)_2$   | 86.10                     | "  |
| 5 — <i>iso</i> propyl cyclohexane, see Hexa hydro cymene |  |                           |  |
| 6 — pyrogallol, 1:3:4:5                                  | $\text{C}_6\text{H}_2(\text{CH}_3)(\text{OH})_2$   | 140.10                    | $\text{C}_7\text{H}_8\text{O}_3$           |
| 7 — pyrrole, 2   | $\text{C}_4\text{H}_3(\text{CH}_3)\text{NH}$   | 81.09                     | $\text{C}_5\text{H}_7\text{N}$             |
| 8 — —, 3   | " "  | 81.09                     | "  |
| 9 — sulphate   | $\text{CH}_3 \cdot \text{O} \cdot \text{SO}_2 \cdot \text{OH}$   | 112.10                    | $\text{CH}_2\text{O}_4\text{S}$            |
| 10 — sulphide  | $(\text{CH}_3)_2\text{S}$  | 62.12                     | $\text{C}_2\text{H}_6\text{S}$             |
| 11 — sulphonic acid                                      | $\text{CH}_3 \cdot \text{SO}_3\text{H}$  | 96.10                     | $\text{CH}_4\text{O}_3\text{S}$            |
| —tetra hydro quinoline, see Kairoline                    |  |                           |  |
| 12 — thiocarbamide                                       | $\text{CS}(\text{NH}_2)(\text{NH} \cdot \text{CH}_3)$  | 90.14                     | $\text{C}_2\text{H}_6\text{N}_2\text{S}$   |
| 13 — thiocyanate, <i>iso</i>                             | $\text{CH}_3 \cdot \text{NCS}$   | 73.10                     | $\text{C}_2\text{H}_3\text{NS}$            |
| 14 — toluidine, <i>o</i>                                 | $\text{CH}_3 \cdot \text{C}_6\text{H}_4 \cdot \text{NH} \cdot \text{CH}_3$   | 121.14                    | $\text{C}_8\text{H}_{11}\text{N}$          |
| 15 — —, <i>m</i>   | " "  | 121.14                    | "  |
| 16 — —, <i>p</i>   | " "  | 121.14                    | "  |
| 17 — uracil  | $\text{CO} \begin{cases} \text{NH} - \text{C} \cdot \text{CH}_3 \\ \parallel \\ \text{NH} \cdot \text{CO} \cdot \text{CH} \end{cases}$ | 126.09                    | $\text{C}_4\text{H}_4\text{O}_2\text{N}_2$ |
| 18 — urea  | $\text{NH}_2 \cdot \text{CO} \cdot \text{NH} \cdot \text{CH}_3$  | 74.08                     | $\text{C}_2\text{H}_5\text{ON}_2$          |
| 19 — uric acid   | $\text{C}_6\text{H}_4\text{N}_4\text{O}_3 \cdot \frac{1}{2}\text{H}_2\text{O}$   | 209.15                    | $\text{C}_6\text{H}_6\text{O}_3\text{N}_4$ |
| 20 Methylal  | $\text{H} \cdot \text{CH}(\text{OCH}_3)_2$   | 76.08                     | $\text{C}_3\text{H}_8\text{O}_2$           |
| 21 Methylene bromide                                     | $\text{CH}_2\text{Br}_2$   | 173.86                    | $\text{CH}_2\text{Br}_2$                   |
| 22 — chloride  | $\text{CH}_2\text{Cl}_2$   | 84.94                     | $\text{CH}_2\text{Cl}_2$                   |
| 23 — disulphonic acid                                    | $\text{CH}_2(\text{SO}_3\text{H})_2$   | 176.16                    | $\text{CH}_4\text{O}_6\text{S}_2$          |
| 24 — iodide  | $\text{CH}_2\text{I}_2$  | 267.86                    | $\text{CH}_2\text{I}_2$                    |
| 25 Milk sugar, lactose                                   | $\text{C}_{12}\text{H}_{22}\text{O}_{11} \cdot 2\text{H}_2\text{O}$  | 378.27                    | $\text{C}_{12}\text{H}_{22}\text{O}_{11}$  |
| 26 Mono acetin   | $\text{C}_3\text{H}_5(\text{OH})_2 \cdot \text{O} \cdot \text{COCH}_3$   | 134.11                    | $\text{C}_5\text{H}_{10}\text{O}_4$        |
| 27 — thioglycerin, see                                   | Glycerin mercaptan   |                           |  |
| 28 Morin   | $\text{C}_{15}\text{H}_{10}\text{O}_7$   | 302.16                    | $\text{C}_{15}\text{H}_{10}\text{O}_7$     |
| 29 Mucic acid  | $\text{C}_6\text{H}_4(\text{OH})_4(\text{COOH})_2$   | 210.11                    | $\text{C}_6\text{H}_{10}\text{O}_8$        |
| 30 Muconic acid  | $\text{C}_6\text{H}_8\text{O}_4$   | 142.08                    | $\text{C}_6\text{H}_8\text{O}_4$           |
| 31 Murexide  | $\text{C}_8\text{H}_4\text{O}_6\text{N}_2 \cdot \text{NH}_4 \cdot \text{H}_2\text{O}$  | 302.18                    | $\text{C}_8\text{H}_7\text{O}_6\text{N}_2$ |
| 32 Myristic acid   | $\text{C}_{13}\text{H}_{27}\text{COOH}$  | 228.31                    | $\text{C}_{14}\text{H}_{28}\text{O}_2$     |
| 33 Myristone   | $(\text{C}_{13}\text{H}_{27})_2 : \text{CO}$   | 394.57                    | $\text{C}_{27}\text{H}_{54}\text{O}$       |

| Density<br>$H_2O=1$ . | Solubility in |          |            | M.P.<br>°C   | B.P.<br>°C.   |    |
|-----------------------|---------------|----------|------------|--------------|---------------|----|
|                       | Water.        | Alcohol. | Ether.     |              |               |    |
| 0.865/16°             | i.            | s.       |            | - 25         | 175—176       | 1  |
| 0.87226/0°            | i.            | s.       |            | - 73.5       | 175           | 2  |
| 0.8124/15°            | v.s.s.        |          |            | F.Pt. - 83.5 | 102           | 3  |
| 0.815/15°             |               |          |            |              | 93—94/752.5mm | 4  |
|                       |               |          |            | 129          |               | 5  |
|                       |               |          |            |              |               | 6  |
|                       |               |          |            |              | 147—148/750   | 7  |
|                       |               |          |            |              | 142—143/742   | 8  |
|                       | v.s.          | s.       | an. m.     | - 30 liq.    |               | 9  |
| 0.845/21°             |               |          |            | liq.         | 37.5          | 10 |
|                       |               |          |            | d. 130       |               | 11 |
|                       | s.            | s.       | s.s.       | 118          |               | 12 |
| 1.069/37°             |               |          |            |              | 119           | 13 |
| 0.973/15°             |               |          |            |              | 206           | 14 |
|                       |               |          |            |              | 206—207       | 15 |
|                       |               |          |            |              | 209—211/761mm | 16 |
|                       |               |          |            |              | (corr.)       |    |
|                       | s.s.          | s.s.     | v.s.s.     | 320 d.       |               | 17 |
|                       | v.s.          | v.s.     | v.s.       | 98           |               | 18 |
|                       | l: 2050 h.    | s.s.     |            | 360 d.       |               | 19 |
| 0.855/18°             | l: 3          |          |            | S.P.—104.8   | 42.3          | 20 |
| 2.4985/15°            |               |          |            | liq.         | 98.5/756      | 21 |
| 1.3778/0°             | i.            |          |            | S.P.—96.7    | 41.6          | 22 |
|                       | v.del.        |          |            |              |               | 23 |
| 3.3326/15°            |               |          |            | 5.7          | 180 d.        | 24 |
| 1.525/4°              | 17: 100/10°   | v.s.s.   | i.         | 203.5        | d. 203        | 25 |
| 1.2                   | s.s.          |          |            | liq.         | 130—132       | 26 |
|                       |               |          |            |              | /2—3mm        |    |
|                       | l: 4000       | s.       | s.         | 285          |               | 27 |
|                       | l: 300/14°    | i.       |            | 224          |               | 28 |
|                       | l: 5000       | h.s.     | s. acetic. | 272 d.       |               | 29 |
|                       | h.s.          | i.       |            |              |               | 30 |
|                       | s.s.          | s.       | s.         | 53.8         | 248/100mm     | 31 |
| 0.8013/76.3~          |               | s.       |            | 75           |               | 32 |
|                       |               |          |            |              |               | 33 |

| Name.                          | Formula.   | Formula Weight. | Empirical Formula. |
|--------------------------------|--|-----------------|--------------------|
| 1 Naphthalene                  | $C_{10}H_8$  | 128.11          | $C_{10}H_8$        |
| 2 — dicarboxylic acid          | $C_{10}H_6(COOH)_2 (1:5)$                                      | 216.12          | $C_{12}H_8O_4$     |
| 3 ———, 1:8                     | " "  | 216.12          | " "                |
| 4 — sulphonic acid, $\alpha$   | $C_{10}H_7(SO_3H).H_2O$  | 226.19          | $C_{10}H_8O_3S$    |
| 5 ———, $\beta$                 | " " $.H_2O$  | 226.19          | " "                |
| 6 Naphthalic acid              | $C_{10}H_6O_3$   | 174.12          | $C_{10}H_6O_3$     |
| 7 Naphthazarin                 | $C_{10}H_6O_2(OH)_2$   | 190.10          | $C_{10}H_6O_4$     |
| 8 Naphthazine                  | $C_{10}H_4.N_2.C_{10}H_6$                                      | 280.22          | $C_{20}H_{12}N_2$  |
| 9 Naphthionic acid, 1:4        | $C_{10}H_6(NH_2)SO_3H.H_2O$                                    | 232.20          | $C_{10}H_9O_3NS$   |
| 10 Naphthoic acid, $\alpha$    | $C_{10}H_7.COOH$   | 172.12          | $C_{11}H_8O_2$     |
| 11 ———, $\beta$                | " "  | 172.12          | " "                |
| 12 — aldehyde, $\alpha$        | $C_{10}H_7.CHO$  | 156.12          | $C_{11}H_8O$       |
| 13 ———, $\beta$                | " "  | 156.12          | " "                |
| 14 Naphthol, $\alpha$          | $C_{10}H_7.OH$   | 144.11          | $C_{10}H_8O$       |
| 15 ———, $\beta$                | " "  | 144.11          | " "                |
| 16 — sulphonic acid, 1:4       | $C_{10}H_6(OH)SO_3H$   | 224.17          | $C_{10}H_8O_3S$    |
| 17 ———, 1:5                    | " "  | 224.17          | " "                |
| 18 ———, 1:8                    | " " $.(H_2O)$  | 224.17          | " "                |
| 19 ———, 1:2                    | " "  | 224.17          | " "                |
| 20 Naphtho nitrile, $\alpha$   | $C_{10}H_7.CN$   | 153.12          | $C_{11}H_7N$       |
| 21 ———, $\beta$                | " "  | 153.12          | " "                |
| 22 — phenazine, $\alpha \beta$ | $C_{10}H_6:N_2:C_6H_4$   | 230.18          | $C_{16}H_{10}N_2$  |
| 23 ———, $\beta \beta$          | " "  | 230.18          | " "                |
| 24 — quinaldine, $\alpha$      | $C_{13}H_8N.CH_3 (2)$  | 193.17          | $C_{14}H_{11}N$    |
| 25 ———, $\beta$                | " " $(3)$  | 193.17          | " "                |
| 26 — quinoline, $\alpha$       | $C_{13}H_9N$   | 179.15          | $C_{13}H_9N$       |
| 27 ———, $\beta$                | " "  | 179.15          | " "                |
| 28 — quinone, 1:4              | $C_{10}H_6O_2$   | 158.10          | $C_{10}H_6O_2$     |
| 29 ———, 1:2                    | " "  | 158.10          | " "                |
| 30 — sultone                   | $C_{10}H_6 \begin{matrix} \diagup SO_2 \\   \\ O \end{matrix}$ | 206.16          | $C_{10}H_6O_3S$    |
| 31 Naphthylamine, $\alpha$     | $C_{10}H_7.NH_2$   | 143.13          | $C_{10}H_9N$       |
| 32 ———, $\beta$                | " "  | 143.13          | " "                |
| 33 Naphthylene diamine, 1:2    | $C_{10}H_6(NH_2)_2$  | 158.15          | $C_{10}H_{10}N_2$  |
| 34 ———, 1:5                    | " "  | 158.15          | " "                |
| 35 ———, 1:8                    | " "  | 158.15          | " "                |

| Density<br>H <sub>2</sub> O=1. | Solubility in—                   |   |   | M.P.<br>°C.  | B.P.<br>°C.         |    |
|--------------------------------|----------------------------------|---|---|--------------|---------------------|----|
|                                | Water.                           | Alcohol.  | Ether.  |              |                     |    |
| 1.145/4°<br>0.9673/95°         | i.                               | 5.29 : 100<br>/15°<br>h.s. (dil.)<br>v.s.s. C <sub>6</sub> H <sub>6</sub> | v.s.  | 50.1         | 217.96              | 1  |
|                                |                                  |   |   | > 286        |                     | 2  |
|                                |                                  |   |   | d.           |                     | 3  |
|                                | v.s.                             | s.  | s.s.  | 85—90        |                     | 4  |
|                                |                                  |   |   | 124—125      |                     | 5  |
|                                | c.v.s.; h.s.                     | s.s.  | s.s.  | 190          |                     | 6  |
|                                | h.s.s.                           | s.  | s.p., s. alk.   | subl.        |                     | 7  |
|                                | s.s. CHCl <sub>3</sub>           | v.s.s.  | v.s.s.  | 275—280      |                     | 8  |
|                                | 1 : 4030/15°                     | v.s.s.  | i.  | d.           |                     | 9  |
|                                | h.s.s.                           | s.  |   | 160          |                     | 10 |
|                                | 0.0058 :                         | s.  | s.  | 182          | >300                | 11 |
|                                | 100/25°                          |   |   |              |                     |    |
|                                | s.s.                             | s.  |   |              | 291.6               | 12 |
|                                | h.s.s.                           | v.s.  | v.s.  | 60           |                     | 13 |
| 1.224/4°                       | h.s.s.                           | s.  | s.  | 96           | 278—280             | 14 |
| 1.217/4°                       | h.s.s.                           | s.  | s.  | 122          | 285—286             | 15 |
|                                | v.s.                             |   |   | d. 170       |                     | 16 |
|                                | s.                               |   |   | 110—120      |                     | 17 |
|                                | v.s.                             |   |   | 107, an. 100 |                     | 18 |
|                                | del.                             |   |   | 101          |                     | 19 |
|                                |                                  | v.s.  |   | 33.5         | 296.5               | 20 |
|                                |                                  | v.s.  | v.s.  | 66.5         | 304—305             | 21 |
| 1.425                          | s. C <sub>6</sub> H <sub>6</sub> | s.s.  | s.s.  | 142          | >360                | 22 |
|                                |                                  |   |   | 233          |                     | 23 |
|                                | h.s.s.                           |   |   | liq.         | >300                | 24 |
|                                | s.s.                             | s.  | s.  | 82           | >300                | 25 |
|                                | v.s.s.                           | v.s.  | v.s.  | 52           | 352                 | 26 |
|                                | h.s.                             | v.s.  | v.s.  | 93.5         | 349.5—350<br>/741mm | 27 |
|                                | s., s. CHCl <sub>3</sub>         | s.  | s. C <sub>6</sub> H <sub>6</sub>                        | 125          |                     | 28 |
|                                | s., s. CHCl <sub>3</sub>         | s.  | s. C <sub>6</sub> H <sub>6</sub>                        | d. 115—120   |                     | 29 |
|                                | s.s.                             | s.s.  | s. C <sub>6</sub> H <sub>6</sub> ,<br>CHCl <sub>3</sub> | 154          | >360                | 30 |
| 1.1011/50°                     | 0.167 : 100, c                   | v.s.  | v.s.  | 51           | 300                 | 31 |
| 1.0614/98°                     | s.                               |   |   | 112          | 306.1               | 32 |
|                                | h.s.                             | v.s.  | s.  | 95           |                     | 33 |
|                                | h.s.                             | s. CHCl   | s.  | 186          | subl.               | 34 |
|                                | s.                               | m.  | m   | 64           | subl.               | 35 |

| Name.                                   | Formula.                   | Formula Empirical<br>Weight. Formula. |
|---|----------------------------|---------------------------------------|
| 1 Naphthyl hydrazine, $\alpha$          | $C_{10}H_7NH.NH_2$         | 158.15 $C_{10}H_{10}N_2$              |
| 2 —, $\beta$                            | " "                        | 158.15 "                              |
| 3 — mercaptan,<br>thionaphthol $\alpha$ | $C_{10}H_7SH$              | 160.17 $C_{10}H_8S$                   |
| 4 —, —, $\beta$                         | " "                        | 160.17 "                              |
| 5 — phenyl ketone, $\alpha$             | $C_{10}H_7.CO.C_6H_5$      | 232.18 $C_{17}H_{12}O$                |
| 6 —, —, $\beta$                         | " "                        | 232.18 "                              |
| 7 — methane, $\alpha$                   | $C_{10}H_7.CH_2.C_6H_5$    | 218.20 $C_{17}H_{14}$                 |
| 8 —, —, $\beta$                         | " "                        | 218.20 "                              |
| 9 Neurine                               | $C_2H_3N(CH_3)_3.OH$       | 103.14 $C_5H_{13}ON$                  |
| 10 Nicotinic acid                       | $C_5H_4N.CO.OH$            | 123.08 $C_5H_5O_2N$                   |
| 11 Nitracetanilide, $o$                 | $NO_2.C_6H_4.NH.COCH_3$    | 180.12 $C_8H_8O_3N_2$                 |
| 12 —, $m$                               | " "                        | 180.12 "                              |
| 13 —, $p$                               | " "                        | 180.12 "                              |
| 14 Nitranilic acid                      | $C_6(NO_2)_2.O_2.(OH)_2$   | 230.07 $C_6H_2O_5N_2$                 |
| 15 Nitraniline, $o$                     | $NO_2.C_6H_4.NH_2$         | 138.10 $C_6H_6O_2N_2$                 |
| 16 —, $m$                               | " "                        | 138.10 "                              |
| 17 —, $p$                               | " "                        | 138.10 "                              |
| 18 Nitro alizarin, 4:1:2                | $C_{14}H_5O_2(NO_2)(OH)_2$ | 285.14 $C_{14}H_7O_6^{1'}$            |
| 19 —, 3:1:2                             | " "                        | 285.14 "                              |
| 20 — anisol, $o$                        | $NO_2.C_6H_4.OCH_3$        | 153.10 $C_7H_7O_3N$                   |
| 21 —, $m$                               | " "                        | 153.10 "                              |
| 22 —, $p$                               | " "                        | 153.10 "                              |
| 23 — anthraquinone, 1                   | $C_{14}H_7O_2.NO_2$        | 253.14 $C_{14}H_7O_4N$                |
| 24 —, 2                                 | " "                        | 253.14 "                              |
| 25 — benzamide, $o$                     | $C_6H_4(NO_2)CONH_2$       | 166.10 $C_7H_6O_3N_2$                 |
| 26 —, $m$                               | " "                        | 166.10 "                              |
| 27 —, $p$                               | " "                        | 166.10 "                              |
| 28 — benzaldehyde, $a$                  | $C_6H_4(NO_2)CHO$          | 151.09 $C_7H_5O_3N$                   |
| 29 —, $m$                               | " "                        | 151.09 "                              |
| 30 —, $p$                               | " "                        | 151.09 "                              |
| 31 — benzene                            | $C_6H_5NO_2$               | 123.08 $C_6H_5O_2N$                   |
| 32 — benzoic acid, $o$                  | $C_6H_4(NO_2)COOH$         | 167.09 $C_7H_5O_4N$                   |
| 33 —, —, $m$                            | " "                        | 167.09 "                              |

| Density<br>H <sub>2</sub> O=1. | Water.  | Solubility in |   | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|---|---------------|---|-------------|-------------|----|
|                                |   | Alcohol.      | Ether.  |             |             |    |
|                                | c.v.s.s.  | h.v.s.s.      | v.s.s.  | 116—117     | 203/20mm.   | 1  |
|                                | i.  | h.s.s.        | s.  | 124—125     |             | 2  |
|                                |   |               |   | liq.        | 285 d       | 3  |
|                                |   |               |   | 79—81       | 286         | 4  |
|                                |   | (abs.)        |   | 75.5        | 385         | 5  |
|                                |   | 1: 41/12      |   |             |             |    |
|                                |   | (abs.)        |   | 82          | 398/745mm   | 6  |
|                                |   | 1: 49/12°     |   |             |             |    |
|                                | s.C <sub>6</sub> H <sub>6</sub> , CS <sub>2</sub> | 1: 30, h.     | s.  | 59          | 350         | 7  |
|                                |   |               |   | 35.5        | 350         | 8  |
|                                | v.s.  | s.            | s.s.  | liq.        |             | 9  |
|                                | h.s.  | s.            | i.  | 228—229     |             | 10 |
|                                | h.v.s   |               | v.s. KOH  | 92—93       |             | 11 |
|                                | h.s.  |               | i. KOH  | 150—152     |             | 12 |
|                                |   |               | s. KOH  | 210—211     |             | 13 |
|                                | v.s.  | v.s.          | i.  | 100         | d. 170      | 14 |
| .442                           | h.s.  | s.            | v.s.  | 71.5        |             | 15 |
| .430                           | 1: 600/18.5°                                      | 11.26:100     | 7.05:100  | 114         | 285         | 16 |
| .437/14°                       | 1: 1250/18.5°                                     | 5.84:100      | 6.1:100   | 148.3       |             | 17 |
|                                | s.s.  | s.            | s. KOH  | 289 d.      |             | 18 |
|                                | s.s.  | v.s.          | s. C <sub>6</sub> H <sub>6</sub> :<br>CHOl <sub>3</sub> | 244 d.      |             | 19 |
| 1.286/20°                      |   |               |   | 9           | 265         | 20 |
|                                |   |               |   | 38          | 258         | 21 |
| .233/20°                       |   |               |   | 54          | 258—260     | 22 |
|                                |   | s.s.          | s.s.  | 220         | subl.       | 23 |
|                                | i.  | v.s.s.        | v.s.s.  | 184—185     | subl.       | 24 |
|                                | h.s.  | s.            |   | 174         | 317         | 25 |
|                                | s.  | s.            |   | 140—142     | 310—315     | 26 |
|                                | s.s.  | s.            |   | 197—198     |             | 27 |
|                                | s.s.  | s.            | s.  | 46          | 153/23mm.   | 28 |
|                                | h.s.  | s.            | s.  | 58          | 164/23mm.   | 29 |
|                                | h.s.  | s.            | s.s.  | 106         |             | 30 |
| .1866/14°                      | i.  | s.            | s.  | 5.7         | 210.9       | 31 |
| .575/4°                        | 0.611:  | 1: 3/10°      | 2.16: 7/11°   | 147—148     |             | 32 |
|                                | 100/16.5°   |               |   |             |             |    |
| .494/4°                        | 0.235:  | 5: 9/10°      | 2.51: 7/11°   | 140.4       |             | 33 |
|                                | 100/16.5°   |               |   |             |             |    |

| Name. |                                  | Formula.                      | Formula Weight. | Empirical Formula. |
|-------|----------------------------------|-------------------------------|-----------------|--------------------|
| 1     | Nitro benzoic acid, <i>p</i>     | $C_6H_4(NO_2)COOH$            | 167.09          | $C_7H_5O_4N$       |
| 2     | — benzoate, ethyl, <i>o</i>      | $C_6H_4(NO_2)COOC_2H_5$       | 195.12          | $C_9H_9O_4N$       |
| 3     | —, —, <i>m</i>                   | " "                           | 195.12          | "                  |
| 4     | —, —, <i>p</i>                   | " "                           | 195.12          | "                  |
| 5     | —, methyl <i>o</i>               | $C_6H_4(NO_2)COOCH_3$         | 181.10          | $C_8H_7O_4N$       |
| 6     | —, —, <i>m</i>                   | " "                           | 181.10          | "                  |
| 7     | —, —, <i>p</i>                   | " "                           | 181.10          | "                  |
| 8     | — benzonitrile, <i>o</i>         | $C_6H_4(NO_2)CN$              | 148.08          | $C_7H_4O_2N_2$     |
| 9     | —, —, <i>m</i>                   | " "                           | 148.08          | "                  |
| 10    | —, —, <i>p</i>                   | " "                           | 148.08          | "                  |
| 11    | — benzoyl formate, <i>o</i>      | $C_6H_4(NO_2)CO.COOH$         | 195.09          | $C_8H_5O_5N$       |
| 12    | — benzyl alcohol, <i>o</i>       | $C_6H_4(NO_2).CH_2OH$         | 153.10          | $C_7H_7O_3N$       |
| 13    | —, —, <i>m</i>                   | " "                           | 153.10          | "                  |
| 14    | —, —, <i>p</i>                   | " "                           | 153.10          | "                  |
| 15    | — — chloride, <i>o</i>           | $C_6H_4(NO_2)CH_2Cl$          | 171.55          | $C_7H_6O_2NCl$     |
| 16    | —, —, <i>m</i>                   | " "                           | 171.55          | "                  |
| 17    | —, —, <i>p</i>                   | " "                           | 171.55          | "                  |
| 18    | — benzylidene chloride, <i>m</i> | $C_6H_4(NO_2)CHCl_2$          | 206.01          | $C_7H_5O_2NCl_2$   |
| 19    | —, —, <i>p</i>                   | " "                           | 206.01          | "                  |
| 20    | — bromoform                      | $C(NO_2)Br_3$                 | 297.78          | $CO_2NBr_3$        |
| 21    | — camphor, $\alpha$              | $C_{10}H_{15}O.NO_2$          | 197.18          | $C_{10}H_{15}O_3N$ |
| 22    | — cinnamic acid, <i>o</i>        | $C_6H_4(NO_2)CH:CH.COOH$      | 193.11          | $C_9H_7O_4N$       |
| 23    | —, —, <i>m</i>                   | " "                           | 193.11          | "                  |
| 24    | —, —, <i>p</i>                   | " "                           | 193.11          | "                  |
| 25    | — cinnamate, ethyl               | $C_6H_4(NO_2)CH:CH.COOC_2H_5$ | 221.15          | $C_{11}H_{11}O_4N$ |
| 26    | — cresol                         | $CH_3.C_6H_3(NO_2)OH$         | 153.10          | $C_7H_7O_3N$       |
| 27    | $CH_3:OH:NO_2=1:2:3$             | " "                           | 153.10          | "                  |
| 28    | —, —, 1:2:5                      | " "                           | 153.10          | "                  |
| 29    | —, —, 1:3:4                      | " "                           | 153.10          | "                  |
| 30    | —, —, 1:3:6                      | " "                           | 153.10          | "                  |
| 31    | —, —, 1:4:3                      | " "                           | 153.10          | "                  |
| 32    | — cumene                         | $C_6H_4(NO_2)CH:(CH_3)_2$     | 165.14          | $C_9H_{11}O_2N$    |
|       | dimethyl aniline, <i>o</i>       | $C_6H_4(NO_2)N:(CH_3)_2$      | 166.14          | $C_8H_{10}O_2N_2$  |
| 33    | —, —, <i>m</i>                   | " "                           | 166.14          | "                  |
| 34    | —, —, <i>p</i>                   | " "                           | 166.14          | "                  |



| Density<br>$H_2O=1.$ | Solubility in   |                 |                      | M.P.<br>°C. | B.P.<br>°C.          |    |
|----------------------|-----------------|-----------------|----------------------|-------------|----------------------|----|
|                      | Water.          | Alcohol.        | Ether.               |             |                      |    |
| .610/20°             | 0.04 : 100/20°  | 0.18 : 9/10°    | 0.22 : 7/11°         | 237         |                      | 1  |
|                      |                 |                 |                      | 29—30       | 173/18mm             | 2  |
|                      |                 |                 |                      | 47          | 296                  | 3  |
|                      |                 |                 |                      | 57          |                      | 4  |
| .2855/20°            |                 |                 |                      |             | 149—151/12mm.        | 5  |
|                      |                 | v.s. $CH_3OH$   |                      | 70          | 279                  | 6  |
|                      |                 |                 |                      | 96          |                      | 7  |
|                      | h.s., s. $CH_2$ | s., s. $CHCl_3$ | s. $C_6H_6$          | 109         |                      | 8  |
|                      | s.s.            | s.              | s.                   | 115         |                      | 9  |
|                      | s.s.            | h.s.            | s. $CHCl_3$          | 147.5—148.5 |                      | 10 |
|                      | warm, m.        |                 |                      | an. 123     |                      | 11 |
|                      | s.s.            | s.              | s.                   | 74          | 168/20mm.            | 12 |
|                      |                 | s.              | s.                   | 27          | 175—180/3            | 13 |
|                      | h.s.            | s.              | s.                   | 93          | 185/12mm.            | 14 |
|                      |                 | s.              |                      | 48—49       |                      | 15 |
|                      |                 | s.              |                      | 45—47       | 173—178/<br>30—35mm. | 16 |
|                      |                 | s.              |                      | 71          |                      | 17 |
|                      | h.s.            | s.              |                      | 65          |                      | 18 |
|                      |                 | s.              | s.                   | 46          |                      | 19 |
| .8                   |                 |                 |                      | 10.2        | 127/48mm             | 20 |
|                      | s. $CHCl_3$     | s.              | s. $C_6H_6$          | 10.3        |                      | 21 |
|                      | i.              | h.s.            |                      | 240         |                      | 22 |
|                      |                 |                 |                      | 196—197     |                      | 23 |
|                      | h.s.s.          | h.s.s.          | s.s.                 | 285—286     |                      | 24 |
|                      | v.s. $C_6H_6$   | v.s.            | v.s., v.s.<br>$OS_2$ | 42          |                      | 25 |
|                      | i.              | v.s.s.          | v.s.s.               | 54          |                      | 26 |
|                      |                 |                 |                      |             |                      | 27 |
|                      | v.s.            | v.s.s.          | v.s.s.               | 94.6—95     |                      | 28 |
|                      | s.s.            | s.s.            | s.s.                 | 56          |                      | 29 |
|                      | v.s.s.          | v.s.s.          | v.s.s.               | 129         |                      | 30 |
|                      |                 | v.s.s.          | v.s.s.               | 127—129     |                      | 31 |
|                      |                 |                 |                      | liq.        |                      | 32 |
|                      |                 |                 |                      |             | 151—153/<br>30—33mm. |    |
|                      | i.              | s.              | s.                   | 60—61       | 280—285 d.           | 33 |
|                      | i.              | s.              |                      | 162—163     |                      | 34 |

| Name.   | Formula.                      | Formula Weight. | Empirical Formula. |
|---|-------------------------------|-----------------|--------------------|
| 1 Nitro diphenyl, <i>o</i>                                  | $C_6H_5.O_6H_4.NO_2$          | 199.14          | $C_{12}H_9O_2N$    |
| 2 —, <i>m</i>   | " "                           | 199.14          | "                  |
| 3 —, <i>p</i>   | " "                           | 199.14          | "                  |
| 4 —ethane   | $C_2H_5.NO_2$                 | 75.06           | $C_2H_5O_2N$       |
| 5 —erythrol   | $C_4H_6(ONO_2)_4$             | 302.11          | $C_4H_6O_{12}N_4$  |
| 6 —glycerin, tri-   | $C_3H_5(ONO_2)_3$             | 227.09          | $C_3H_5O_9N_3$     |
| 7 —, di-, $\alpha \gamma$                                   | $C_3H_5(OH)(ONO_2)_2$         | 183.09          | $C_3H_6O_7N_2$     |
| 8 —, di-, $\alpha \beta$                                    | " "                           | 183.09          | "                  |
| 9 —, mono-, $\alpha$  | $C_3H_5(OH)_2(ONO_2)$         | 137.08          | $C_3H_7O_5N$       |
| 10 —, mono-, $\beta$  | " "                           | 137.08          | "                  |
| 11 —guanidine   | $CH_3N_3.NO_2$                | 104.07          | $CH_3O_2N_4$       |
| 12 —isatin  | $C_8H_4NO_2.NO_2$             | 192.09          | $C_8H_4O_4N_4$     |
| 13 —isoquinoline  | $C_8H_3(NO_2)_2.C_3H_3N.H_2O$ | 210.11          | $C_9H_6O_2N_2$     |
| 14 —mannitol  | $C_6H_8(ONO_2)_6$             | 452.15          | $C_6H_8O_{18}N_6$  |
| 15 —mesitylene,<br>( $CH_3$ ) <sub>3</sub> : $NO_2=1:3:5:3$ | $C_6H_2(CH_3)_3.NO_2$         | 165.14          | $C_9H_{11}O_2N$    |
| 16 —methane   | $CH_3.NO_2$                   | 61.04           | $CH_3O_2N$         |
| 17 —naphthalene, $\alpha$                                   | $C_{10}H_7.NO_2$              | 173.12          | $C_{10}H_7O_2N$    |
| 18 —, $\beta$   | " "                           | 173.12          | "                  |
| 19 —naphthol, 1:2   | $C_{10}H_6OH.NO_2$            | 189.12          | $C_{10}H_7O_3N$    |
| 20 —, 1:4   | " "                           | 189.12          | "                  |
| 21 —, 1:5   | " "                           | 189.12          | "                  |
| 22 —, 2:1   | " "                           | 189.12          | "                  |
| 23 —, 2:5   | " "                           | 189.12          | "                  |
| 24 —, 2:6   | " "                           | 189.12          | "                  |
| 25 —naphthylamine, 1:2                                      | $C_{10}H_6NH_2.NO_2$          | 188.13          | $C_{10}H_8O_2N_2$  |
| 26 —, 1:4   | " "                           | 188.13          | "                  |
| 27 —, 2:1   | " "                           | 188.13          | "                  |
| 28 —, 1:8   | " "                           | 188.13          | "                  |
| 29 —, 1:5   | " "                           | 188.13          | "                  |
| 30 —, 2:5   | " "                           | 188.13          | "                  |
| 31 —, 2:8   | " "                           | 188.13          | "                  |
| 32 —phenetol, <i>o</i>                                      | $C_2H_5.O.C_6H_4.NO_2$        | 167.12          | $C_8H_9O_3N$       |
| 33 —, <i>m</i>  | " "                           | 167.12          | "                  |
| 34 —, <i>p</i>  | " "                           | 167.12          | "                  |
| 35 —phenol, <i>o</i>  | $C_6H_4OH.NO_2$               | 139.08          | $C_6H_5O_3N$       |
| 36 —, <i>m</i>  | " "                           | 139.08          | "                  |
| 37 —, <i>p</i>  | " "                           | 139.08          | "                  |

| Density<br>$H_2O=1$ . | Solubility in |                    |                 | M.P.<br>°C. | B.P.<br>°C.   |    |
|-----------------------|---------------|--------------------|-----------------|-------------|---------------|----|
|                       | Water.        | Alcohol.           | Ether.          |             |               |    |
|                       |               |                    |                 | 37          | 320           | 1  |
|                       |               |                    |                 | 61          |               | 2  |
|                       | s. $CHCl_3$   | h.s.               | s.              | 114—114.5   | 340           | 3  |
| 1.0582/13°            | i.            |                    |                 |             | 114—114.8     | 4  |
|                       | h.s.          | s.                 |                 | 61          | expl.         | 5  |
| 1.6009/15°            | 0.16 : 100    | 1 : 3.5            | m.              | 13.3        | expl. 260     | 6  |
| 1.47                  | 7.7 : 100     |                    |                 | liq.        | 146—148       | 7  |
|                       |               |                    |                 | liq.        | /15 mm.       | 8  |
| 1.40                  | 70 : 10       | v.s.               | v.s.            | 58          | 155—160       | 9  |
|                       |               |                    |                 | 54          | /15mm.        | 10 |
|                       | c.v.s.s.      | v.s.s.             | i.              | 230 d.      |               | 11 |
|                       | s.s.          | s.                 | s. KOH          | 226—230     |               | 12 |
|                       | h.s.          | s.                 |                 | 110         |               | 13 |
| 1.604/0°              | h.s.          | 1 : 34.4<br>/12.8° | 1 : 24.4<br>/9° | 108         |               | 14 |
|                       | s. $C_6H_6$   | s.                 | s.              | 41—42       | 255           | 15 |
| 1.441/15°             | s.s.          |                    | s. alk.         | — 26.5      | 101/762mm     | 16 |
| 1.331/4°              |               |                    |                 | 61          | 304           | 17 |
|                       | s. $CHCl_3$   | s.                 |                 | 79          | 160—170       | 18 |
|                       |               |                    |                 |             | /15mm.        |    |
|                       | v.s.s.        | s.s. (dil.)        |                 | 128         |               | 19 |
|                       | h.s.          | v.s.               | s. acetic.      | 164         |               | 20 |
|                       |               |                    |                 | 171         |               | 21 |
|                       |               |                    |                 | 165         |               | 22 |
|                       |               |                    |                 | 103         |               | 23 |
|                       |               |                    |                 | 144—145     |               | 24 |
|                       |               | s.                 |                 | 144         |               | 25 |
|                       |               | s.                 | s. acetic.      | 191         |               | 26 |
|                       | h.s.          | s.                 |                 | 123—124     |               | 27 |
|                       |               |                    |                 | 96—97       |               | 28 |
|                       | s.            |                    |                 | 118—119     |               | 29 |
|                       |               |                    |                 | 143.5       |               | 30 |
|                       |               |                    |                 | 103.5       |               | 31 |
|                       |               |                    |                 | 2.1         | 267—268/757mm | 32 |
|                       |               |                    |                 | 34          | 264           | 33 |
| 1.180/15°             |               |                    |                 | 57.8        | 283/758mm     | 34 |
| 1.2945/45.2°          | h.s.          | s.                 | s.              | 44.3        | 214           | 35 |
| 1.492                 | h.s.          | v.s.               | v.s.            | 96          | 194/70mm.     | 36 |
| 1.2809/14°            | s.s.          | v.s.               |                 | 114         |               | 37 |

| Name. |   | Formula.  | Formula Weight. | Empirical Formula.                          |
|-------|---|---|-----------------|---|
| 1     | Nitro phenyl acetic acid, <i>o</i>                                  | $\text{NO}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{CH}_2 \cdot \text{COOH}$  | 181.10          | $\text{C}_8\text{H}_7\text{O}_4\text{N}$    |
| 2     | -----, <i>m</i>   | " "   | 181.10          | "   |
| 3     | -----, <i>p</i>   | " "   | 181.10          | "   |
| 4     | --- hydrazine, <i>o</i>   | $\text{NO}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{NH} \cdot \text{NH}_2$    | 153.11          | $\text{C}_6\text{H}_7\text{O}_2\text{N}_3$  |
| 5     | -----, <i>m</i>   | " "   | 153.11          | "   |
| 6     | -----, <i>p</i>   | " "   | 153.11          | "   |
| 7     | --- propiolic acid, <i>o</i>  | $\text{C}_6\text{H}_4(\text{NO}_2)\text{C} \equiv \text{C} \cdot \text{COOH}$ | 191.10          | $\text{C}_9\text{H}_5\text{O}_4\text{N}$    |
| 8     | -----, <i>p</i>   | " "   | 191.10          | "   |
|       | — phthalic acid,<br>$\text{COOH} : \text{COOH} : \text{NO}_2 =$     |   |                 |   |
| 9     | 1 : 2 : 3   | $\text{C}_6\text{H}_3(\text{NO}_2)(\text{COOH})_2$                            | 211.11          | $\text{C}_8\text{H}_5\text{O}_6\text{N}$    |
| 10    | 1 : 2 : 4   | " "   | 211.11          | "   |
| 11    | 1 : 3 : 5   | " "   | 211.11          | "   |
| 12    | 1 : 3 : 2   | " "   | 211.11          | "   |
| 13    | 1 : 3 : 4   | " "   | 211.11          | "   |
| 14    | 1 : 4 : 2   | " "   | 211.11          | "   |
|       | — pseudo cumene,<br>$(\text{CH}_3)_3 : \text{NO}_2 = 1 : 2 : 4 : 3$ | $\text{C}_6\text{H}_3(\text{NO}_2)(\text{CH}_3)_3$                            | 165.14          | $\text{C}_9\text{H}_{11}\text{O}_2\text{N}$ |
| 15    | 1 : 2 : 4 : 5   | " "   | 165.14          | "   |
| 16    | 1 : 2 : 4 : 6   | " "   | 165.14          | "   |
| 17    | — quinoline, 8  | $\text{C}_9\text{H}_6\text{N} \cdot \text{NO}_2$                              | 174.11          | $\text{C}_9\text{H}_6\text{O}_2\text{N}_2$  |
| 18    | —, 7  | " "   | 174.11          | "   |
| 19    | —, 6  | " "   | 174.11          | "   |
| 20    | —, 5  | $\text{C}_9\text{H}_6\text{N} \cdot \text{NO}_2$                              | 174.11          | $\text{C}_9\text{H}_6\text{O}_2\text{N}_2$  |
|       | — salicylic acid,<br>$\text{COOH} : \text{OH} : \text{NO}_2 =$      |   |                 |   |
| 21    | 1 : 2 : 6   | $\text{C}_6\text{H}_3(\text{NO}_2)(\text{OH})\text{COOH}$                     | 183.09          | $\text{C}_7\text{H}_5\text{O}_5\text{N}$    |
| 22    | 1 : 2 : 5   | " "   | 183.09          | "   |
| 23    | 1 : 2 : 3   | " " $(\cdot\text{H}_2\text{O})$   | 183.09          | "   |
| 24    | 1 : 2 : 4   | " " $(\cdot\text{H}_2\text{O})$   | 183.09          | "   |
| 25    | 1 : 3 : 2   | " " $(\cdot\text{H}_2\text{O})$   | 183.09          | "   |
| 26    | 1 : 3 : 4   | " " $(\cdot\text{H}_2\text{O})$   | 183.09          | "   |
| 27    | 1 : 3 : 5   | " " $(\cdot\text{H}_2\text{O})$   | 183.09          | "   |
| 28    | 1 : 3 : 6   | " "   | 183.09          | "   |
| 29    | 1 : 4 : 3   | " "   | 183.09          | "   |
| 30    |   | " "   | 183.09          | "   |

| Density<br>$H_2O=1.$ | Solubility in    |          |                      | M.P.<br>°C.    | B.P.<br>°C. |    |
|----------------------|------------------|----------|----------------------|----------------|-------------|----|
|                      | Water.           | Alcohol. | Ether.               |                |             |    |
|                      | v.s.             |          |                      | 141            |             | 1  |
|                      | s.               |          |                      | 117            |             | 2  |
|                      | c.v.s.           | s.s.     |                      | 114            |             | 3  |
|                      | h.s.s.; c.s.     | s.s.     | s.s.                 | 90             |             | 4  |
|                      | h.v.s.           | v.s.     |                      | 93             |             | 5  |
|                      |                  | h.s.     |                      | 157 d.         |             | 6  |
|                      | h.s.             | s.       | s., s.s.<br>$CHCl_3$ | 155—156 d.     |             | 7  |
|                      | s.s.             | h.s.     | s.                   | 181            | d           | 8  |
|                      | h.s.             | v.s.     | s.                   | 218            |             | 9  |
|                      | v.s.             | v.s.     | v.s.                 | 161            |             | 10 |
|                      | s.s.             | v.s.     |                      | 248—249        |             | 11 |
|                      |                  |          |                      | 315            |             | 12 |
|                      |                  |          |                      | 246            |             | 13 |
|                      |                  |          |                      | 270            |             | 14 |
|                      |                  | s.       |                      | 30             |             | 15 |
|                      |                  | s.       |                      | 20             | 265         | 16 |
|                      |                  |          |                      | 71             |             | 17 |
|                      | h.s.             | s.       | s., s. $C_6H_6$      | 88—89          |             | 18 |
|                      |                  | c.v.s.s  | s.                   | 132—133        |             | 19 |
|                      | h.s.             | h.s.     | s.s., s. $C_6H_6$    | 149—150        | subl.       | 20 |
|                      | h.s.s.           |          |                      | 72             | subl.       | 21 |
|                      | s. acetone       | s.s.     | v.s.s.               | 130            |             | 22 |
| 1.650                | 1:1475<br>/15.5° | v.s.     |                      | 228            |             | 23 |
|                      | 1:770<br>/15.5°  | s.       | s., s. $C_6H_6$      | 125, an<br>144 |             | 24 |
|                      |                  |          |                      | 235            |             | 25 |
|                      |                  |          |                      | 178            |             | 26 |
|                      |                  |          |                      | 230            |             | 27 |
|                      |                  |          |                      | 167            |             | 28 |
|                      |                  |          |                      | 169            |             | 29 |
|                      |                  |          |                      | 185            |             | 30 |

| Name. |   | Formula.  | Formula Weight. | Empirical Formula.  |
|-------|---|---|-----------------|---|
| 1     | Nitro resorcin,<br>(OH) <sub>2</sub> :NO <sub>2</sub> =1:3:2        | (OH) <sub>2</sub> :C <sub>6</sub> H <sub>3</sub> .NO <sub>2</sub>                 | 155.08          | C <sub>6</sub> H <sub>5</sub> O <sub>4</sub> N              |
| 2     | Nitroso benzene   | C <sub>6</sub> H <sub>5</sub> .NO   | 107.08          | C <sub>6</sub> H <sub>5</sub> ON                            |
| 3     | — diethylamine  | (C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> :N.NO                               | 102.12          | C <sub>4</sub> H <sub>10</sub> ON <sub>2</sub>              |
| 4     | — dimethyl aniline, <i>p</i>  | (CH <sub>3</sub> ) <sub>2</sub> :N.C <sub>6</sub> H <sub>4</sub> .NO              | 150.14          | C <sub>8</sub> H <sub>10</sub> ON <sub>2</sub>              |
| 5     | — diphenylamine, N  | (C <sub>6</sub> H <sub>5</sub> ) <sub>2</sub> :N.NO                               | 198.16          | C <sub>12</sub> H <sub>10</sub> ON <sub>2</sub>             |
| 6     | — naphthol, 1:2   | C <sub>10</sub> H <sub>6</sub> OH.NO  | 173.11          | C <sub>10</sub> H <sub>7</sub> O <sub>2</sub> N             |
| 7     | —, 1:4  | " "   | 173.11          | "   |
| 8     | —, 2:1  | " "   | 173.11          | "   |
| 9     | — phenol, <i>p</i>  | OH.C <sub>6</sub> H <sub>4</sub> .NO  | 123.09          | C <sub>6</sub> H <sub>5</sub> O <sub>2</sub> N              |
| 10    | Nitro styrolene, <i>o</i>   | NO <sub>2</sub> .C <sub>6</sub> H <sub>4</sub> .CH:CH <sub>2</sub>                | 149.10          | C <sub>8</sub> H <sub>7</sub> O <sub>2</sub> N              |
| 11    | —, <i>m</i>   | " "   | 149.10          | "   |
| 12    | —, <i>p</i>   | " "   | 149.10          | "   |
| 13    | — thiophen  | C <sub>4</sub> H <sub>3</sub> S.NO <sub>2</sub>                                   | 129.11          | C <sub>4</sub> H <sub>3</sub> O <sub>2</sub> NS             |
| 14    | — toluene, <i>o</i>   | C <sub>6</sub> H <sub>4</sub> (NO <sub>2</sub> )CH <sub>3</sub>                   | 137.10          | C <sub>7</sub> H <sub>7</sub> O <sub>2</sub> N              |
| 15    | —, <i>m</i>   | " "   | 137.10          | "   |
| 16    | —, <i>p</i>   | " "   | 137.10          | "   |
|       | — toluidine,<br>CH <sub>3</sub> :NH <sub>2</sub> :NO <sub>2</sub> = |   |                 |   |
| 17    | 1:2:3   | C <sub>6</sub> H <sub>3</sub> (CH <sub>3</sub> )(NH <sub>2</sub> )NO <sub>2</sub> | 152.12          | C <sub>7</sub> H <sub>8</sub> O <sub>2</sub> N <sub>2</sub> |
| 18    | 1:2:4   | " "   | 152.12          | "   |
| 19    | 1:2:5   | " "   | 152.12          | "   |
| 20    | 1:3:4   | " "   | 152.12          | "   |
| 21    | 1:2:6   | " "   | 152.12          | "   |
| 22    | 1:3:2   | " "   | 152.12          | "   |
| 23    | 1:3:5   | " "   | 152.12          | "   |
| 24    | 1:3:6   | " "   | 152.12          | "   |
| 25    | 1:4:2   | " "   | 152.12          | "   |
| 26    | 1:4:3   | " "   | 152.12          | "   |
| 27    | — urea  | NH <sub>2</sub> .CO.NH.NO <sub>2</sub>  | 105.06          | CH <sub>3</sub> O <sub>3</sub> N <sub>3</sub>               |
| 28    | — urethane  | C <sub>2</sub> H <sub>5</sub> .O.CO.NH.NO <sub>2</sub>                            | 134.08          | C <sub>3</sub> H <sub>6</sub> O <sub>4</sub> N <sub>2</sub> |
|       | — xylene,<br>CH <sub>3</sub> :CH <sub>3</sub> :NO <sub>2</sub> =    |   |                 |   |
| 29    | 1:2:3   | C <sub>6</sub> H <sub>3</sub> (CH <sub>3</sub> )NO <sub>2</sub>                   | 151.12          | C <sub>8</sub> H <sub>9</sub> O <sub>2</sub> N              |
| 30    | 1:2:4   | " "   | 151.12          | "   |
| 31    | 1:3:2   | " "   | 151.12          | "   |
| 32    | 1:3:4   | " "   | 151.12          | "   |
| 33    | 1:3:5   | " "   | 151.12          | "   |
| 34    | 1:4:2   | " "   | 151.12          | "   |

| Density<br>$H_2O=1$ . | Solubility in |                 |                   | M.P.<br>°C. | B.P.<br>°C.      |    |
|-----------------------|---------------|-----------------|-------------------|-------------|------------------|----|
|                       | Water.        | Alcohol.        | Ether.            |             |                  |    |
|                       |               |                 | s.                | 85          |                  | 1  |
| 0.951/17.5°           |               | s.              | s.                | 68          | 176.9            | 2  |
|                       | i.            | s.              | s.                | 85          |                  | 3  |
|                       |               | h.s.            | h.v.s. $C_6H_6$   | 66.5        |                  | 4  |
|                       |               | s.              | s. acetone        | 162—164     |                  | 5  |
|                       | h.v.s.s.      | 1:42/13°        | s.                | 190         |                  | 6  |
|                       |               |                 |                   | 112         |                  | 7  |
|                       | s.            | s.              | s.                | 140 d.      |                  | 8  |
|                       | s. $H_2SO_4$  |                 |                   | 12—12.5     | d.               | 9  |
|                       | s. $CHCl_3$   | s. (abs.)       | s.                | 16          | 230—231          | 10 |
|                       |               | s.              | v.s.              | 58          | 250—260          | 11 |
|                       | i. alk.       |                 |                   | 44          | 224—225          | 12 |
| 1.1629/20°            | i.            | s.              |                   | 3.85        | 222.3            | 13 |
| 1.168/22°             |               | s.              |                   | 16.1        | 230—231          | 14 |
|                       |               |                 |                   |             | /756mm           | 15 |
| 1.1232/54°            |               | s.              |                   | 51.6—51.9   | 237.7            | 16 |
|                       | s. $CHCl_3$   | s.              | s., s. $C_6H_6$   | 91.5        |                  | 17 |
| 1.365                 | s. acetone    | s.              | s.                | 104—105     |                  | 18 |
| 1.366                 | h.s.s.        | s.              |                   | 127—126     |                  | 19 |
|                       |               |                 |                   | 109         |                  | 20 |
| 1.378                 | h.s.s.        | v.s.            | s., v.s. $C_6H_6$ | 91.5        |                  | 21 |
|                       | c.s.s.        | s.              |                   | 53          |                  | 22 |
|                       | v.s.s.        | s., s. $C_6H_6$ | v.s.              | 98—98.4     |                  | 23 |
|                       |               |                 | s. ac.            | 138         |                  | 24 |
|                       | s.            | s.s. $CS_2$     |                   | 77.5        |                  | 25 |
| 1.312                 | h.v.s.s.      | s.              |                   | 116         |                  | 26 |
|                       | s.            | s.              |                   |             |                  | 27 |
|                       | s.            | s.              | i                 | 64          | 140 d            | 28 |
| 1.147/15°             |               |                 |                   | 7—9         | 250/739mm        | 29 |
| 1.139/30°             |               | m. >30°         |                   | 29          | 258              | 30 |
| 1.112/15°             |               |                 |                   | 13          | 225/744mm.       | 31 |
| 1.126/17.5            |               |                 |                   |             | 237—239          | 32 |
|                       |               | s.              | s.                | 74—75       | 273/739mm.       | 33 |
| 1.132/15°             |               |                 |                   | liq.        | 238.5—239/739mm. | 34 |

| Name.                         | Formula.                           | Formula Weight. | Empirical Formula.   |
|-------------------------------|------------------------------------|-----------------|----------------------|
| 1 Nonadecane                  | $C_{19}H_{40}$                     | 268.42          | $C_{19}H_{40}$       |
| 2 Nonane, norm.               | $CH_3.(CH_2)_7.CH_3$               | 128.21          | $C_9H_{20}$          |
| 3 —, isobutyl isoamyl         | $(CH_3)_2:CH.(CH_2)_2.CH:$         | 128.21          | "                    |
| 4 Nonyl alcohol, norm.        | $C_9H_{19}OH$ $(CH_3)_2$           | 144.21          | $C_9H_{20}O$         |
| 5 —, ethyl hexyl carbinol     | $C_2H_5.CHOH.C_6H_{13}$            | 144.21          | "                    |
| 6 Nonylene                    | $C_{18}H_{18}$                     | 126.15          | $C_9H_{18}$          |
| 7 Nonylic acid                | $C_{17}H_{34}COOH$                 | 158.15          | $C_9H_{18}O_2$       |
| 8 Nucin, see                  | Hydroxy naphthoquinone             |                 | "                    |
| 9 Octa decane                 | $C_{18}H_{38}$                     | 254.39          | $C_{18}H_{38}$       |
| 10 — decyl alcohol            | $C_{18}H_{38}O$                    | 270.39          | $C_{18}H_{38}O$      |
| 11 — decylene, norm.          | $CH_3.(CH_2)_{15}.CH:CH_2$         | 252.38          | $C_{18}H_{36}$       |
| 12 —, sec.                    | $C_{18}H_{36}$                     | 252.38          | "                    |
| 13 Octane, norm.              | $C_8H_{18}$                        | 114.18          | $C_8H_{18}$          |
| 14 —, di-isobutyl             | $(CH_3)_2:CH.(CH_2)_3.CH:$         | 114.18          | "                    |
| 15 Octyl alcohol, norm.       | $C_8H_{18}O$ $(CH_3)_2$            | 130.18          | $C_8H_{18}O$         |
| 16 —, methyl hexyl carbinol   | $CH_3.(CH_2)_5.CHOH.CH_3$          | 130.18          | "                    |
| 17 —, diethyl propyl carbinol | $(C_2H_5)_2.COH.C_3H_7$            | 130.18          | "                    |
| 18 — amine, norm.             | $C_8H_{17}.NH_2$                   | 129.20          | $C_8H_{19}N$         |
| 19 —, sec.                    | $CH_3.CH(NH_2).C_6H_{13}$          | 129.20          | "                    |
| 20 — chloride, norm.          | $C_8H_{17}Cl$                      | 148.64          | $C_8H_{17}Cl$        |
| 21 —, sec.                    | "                                  | 148.64          | "                    |
| 22 Octylene, norm.            | $C_8H_{16}$                        | 112.17          | $C_8H_{16}$          |
| 23 —, di-isopropyl ethylene   | $(CH_3)_2:CH.CH:CH.CH:$ $(CH_3)_2$ | 112.17          | "                    |
| 24 —, di-iso butylene         | $(CH_3)_2C:CH.CH:O(CH_3)_2$        | 112.17          |                      |
| 25 Cœnanthic acid, see        | Heptylic acid                      |                 |                      |
| 26 Cœnanthine, see            | Heptene                            |                 |                      |
| 27 Cœnanthol, see             | Heptyl alcohol                     |                 |                      |
| 28 Oleic acid                 | $C_{17}H_{33}COOH$                 | 282.36          | $C_{18}H_{34}O_2$    |
| 29 Olein                      | $C_3H_5(C_{18}H_{33}O_2)_3$        | 885.12          | $C_{57}H_{104}O_6$   |
| 30 Opianic acid               | $C_6H_2(OCH_3)_2(OHO)COOH$         | 210.13          | $C_{10}H_{10}O_5$    |
| 31 Opianin, see               | Narcotine                          |                 |                      |
| 32 Orceïne                    | $C_{28}H_{24}N_2O_7$               | 500.35          | $C_{28}H_{24}N_2O_7$ |
| 33 Orcinol, see               | Dihydroxy toluene                  |                 |                      |
| 34 — phthalein                | $C_{22}H_{16}O_5$                  | 360.24          | $C_{22}H_{16}O_5$    |
| 35 Orsellie acid, 2:6:4:1     | $C_6H_2(OH)_2(CH_3)COOH$           | 168.10          | $C_8H_8O_4$          |



| Density<br>H <sub>2</sub> O=1. | Solubility in        |          |                       | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|----------------------|----------|-----------------------|-------------|-------------|----|
|                                | Water.               | Alcohol. | Ether.                |             |             |    |
| 0.777/32°                      |                      |          |                       | 32          | 330         | 1  |
| 0.7177/20°                     |                      |          |                       | liq.        | 150         | 2  |
| 0.7247/0°                      |                      |          |                       |             | 132—133     | 3  |
| 0.855/18.5°                    |                      |          |                       | - 5         | 213.5       | 4  |
| 0.825/20°                      |                      |          |                       | liq.        | 195/750mm.  | 5  |
| 0.7433/20°                     | s.                   | s.       | s.                    |             | 147—148     | 6  |
|                                |                      |          |                       | 12—12.5     | 254         | 7  |
|                                |                      |          |                       |             |             | 8  |
| 0.7668/28°                     |                      |          |                       | 30          | 305—307     | 9  |
| 0.8124/59°                     |                      | s.       |                       | 59          | 210.5/15    | 10 |
| 0.791/18°                      |                      |          |                       | 18          | 179/15mm.   | 11 |
| 0.942/15°                      | i.                   | v.s.s.   | s, s. CS <sub>2</sub> | 63—64       | 440         | 12 |
| 0.7188/0°                      |                      |          |                       | liq.        | 125.8       | 13 |
| 0.7001/12°                     |                      |          |                       | liq.        | 108.5       | 14 |
| 0.8375/0°                      |                      |          |                       | - 15        | 195.5       | 15 |
| 0.823/16°                      |                      |          |                       |             | 179.5       | 16 |
| 0.8379/20°                     |                      |          |                       |             | 160.5       | 17 |
|                                |                      |          |                       |             |             |    |
|                                |                      |          |                       |             |             |    |
| 0.786                          |                      |          |                       |             | 185—187     | 18 |
|                                |                      |          |                       |             | 162.5       | 19 |
|                                |                      |          |                       |             | 179.5—180.5 | 20 |
|                                |                      |          |                       |             | 175         | 21 |
|                                |                      |          |                       |             | 122—123     | 22 |
| 0.7217/17°                     |                      |          |                       | liq.        | 116—120     | 23 |
| 0.734/0°                       |                      |          |                       |             | 102.5/756   | 24 |
|                                |                      |          |                       |             |             | 25 |
|                                |                      |          |                       |             |             | 26 |
|                                |                      |          |                       |             |             | 27 |
|                                |                      |          |                       |             |             |    |
| 0.898/14°                      | i.                   | s.       | s.                    | 14          | 286/100     | 28 |
|                                | i.                   | v.s.s.   | v.s.                  | - 5         |             | 29 |
|                                | 1: 400, o.           | s.       | s.                    | 150         |             | 30 |
|                                | 1: 60, h.            |          |                       |             |             |    |
|                                |                      |          |                       |             |             | 31 |
|                                | s. CHCl <sub>3</sub> | s.       | s.                    |             |             | 32 |
|                                |                      |          |                       |             |             | 33 |
|                                | i.                   | s.       | i., s. alk.           | d. 230      |             | 34 |
|                                | s.                   | v.s.     | 1: 4.5/20°            | d. 176      |             | 35 |

| Name.                  | Formula.  | Formula Weight. | Empirical Formula.                               |
|------------------------|---|-----------------|--|
| 1 Ortho acetate, ethyl | $\text{CH}_3.\text{C}(\text{OC}_2\text{H}_5)_2$   | 162.18          | $\text{C}_8\text{H}_{18}\text{O}_3$              |
| 2 — formate, ethyl     | $\text{CH}(\text{OC}_2\text{H}_5)_3$  | 148.16          | $\text{C}_7\text{H}_{16}\text{O}_3$              |
| 3 Osotriazole          | $\begin{array}{c} \text{HC}=\text{N} \\   \\ \text{HC}=\text{N} \end{array} \text{NH}$                            | 69.06           | $\text{C}_2\text{H}_3\text{N}_3$                 |
| 4 Oxalacetic ester     | $\text{O}_2\text{H}_5.\text{OOC}.\text{CO}.\text{CH}_2.\text{COO}.\text{C}_2\text{H}_5$                           | 188.14          | $\text{C}_8\text{H}_{12}\text{O}_5$              |
| 5 Oxalic acid          | $\text{COOH}.\text{COOH}.\text{2H}_2\text{O}$   | 126.06          | $\text{C}_2\text{H}_2\text{O}_4$                 |
| 6 Oxalate, ammonium    | $(\text{COONH}_4)_2.(\text{H}_2\text{O})$   | 124.09          | $\text{C}_2\text{H}_8\text{O}_4\text{N}_2$       |
| 7 —, calcium           | $(\text{COO})_2\text{Ca}.\text{(H}_2\text{O)}$  | 134.08          | $\text{C}_2\text{O}_2\text{Ca}$                  |
| 8 —, potassium         | $(\text{COOK})_2.(\text{H}_2\text{O})$  | 166.21          | $\text{C}_2\text{O}_2\text{K}$                   |
| 9 —, — hydrogen        | $(\text{COO})_2\text{HK}$   | 128.12          | $\text{C}_2\text{H}_4\text{O}_4\text{K}$         |
| 10 —, — —              | $(\text{COO})_2\text{HK}(\text{COOH})_2.\text{2H}_2\text{O}$  | 254.17          | $\text{C}_2\text{H}_4\text{O}_8\text{K}$         |
| 11 —, allyl            | $(\text{COO}.\text{C}_3\text{H}_5)_2$   | 170.12          | $\text{C}_4\text{H}_8\text{O}_4$                 |
| 12 —, ethyl            | $(\text{COO}.\text{C}_2\text{H}_5)_2$   | 146.11          | $\text{C}_4\text{H}_{10}\text{O}_4$              |
| 13 —, methyl           | $(\text{COO}.\text{CH}_3)_2$  | 118.07          | $\text{C}_4\text{H}_6\text{O}_4$                 |
| 14 Oxaluramide         | $\text{C}_3\text{H}_5\text{N}_3\text{O}_3$  | 131.09          | $\text{C}_3\text{H}_5\text{O}_3\text{N}_3$       |
| 15 Oxaluric acid       | $\text{NH}_2.\text{CO}.\text{NH}.\text{CO}.\text{COOH}$   | 132.07          | $\text{C}_3\text{H}_5\text{O}_3\text{N}_3$       |
| 16 Oxalyl chloride     | $(\text{COCl})_2$   | 126.93          | $\text{C}_2\text{O}_2\text{Cl}_2$                |
| 17 Oxamethane          | $\text{C}_2\text{O}_2\text{NH}_2(\text{OC}_2\text{H}_5)$  | 117.09          | $\text{C}_2\text{H}_7\text{O}_3\text{N}$         |
| 18 Oxamide             | $\text{C}_2\text{O}_2(\text{NH}_2)_2$   | 88.06           | $\text{C}_2\text{H}_4\text{O}_2\text{N}_2$       |
| 19 Oxaminic acid       | $\text{C}_2\text{O}_2(\text{NH}_2)_2\text{OH}$  | 89.04           | $\text{C}_2\text{H}_3\text{O}_3\text{N}_2$       |
| 20 Oxanilide           | $\text{C}_2\text{O}_2(\text{NH}.\text{C}_6\text{H}_5)$  | 240.19          | $\text{C}_{14}\text{H}_{12}\text{O}_2\text{N}_2$ |
| 21 Oxanthrol           | $\text{C}_6\text{H}_4 : (\text{CO})\text{CH}(\text{OH}) : \text{O}_6\text{H}_4$                                   | 210.15          | $\text{C}_{14}\text{H}_{10}\text{O}_2$           |
| 22 Oximide             | $\begin{array}{c} \text{CC} \\   \\ \text{CO} \end{array} \text{NH}$  | 61.09           | $\text{C}_2\text{HO}_2\text{N}$                  |
| 23 Oxindole            | $\text{C}_6\text{H}_4 \begin{array}{c} \text{CH}_2 \\ \diagup \quad \diagdown \\ \text{NH} \end{array} \text{CO}$ | 133.11          | $\text{C}_8\text{H}_7\text{ON}$                  |
| 24 Palmitic acid       | $\text{C}_{15}\text{H}_{31}\text{COOH}$   | 256.34          | $\text{C}_{16}\text{H}_{32}\text{O}_2$           |
| 25 Palmitin            | $\text{C}_{15}\text{H}_{31}(\text{C}_{16}\text{H}_{31}\text{O}_2)_3$  | 807.04          | $\text{C}_{51}\text{H}_{93}\text{O}_6$           |
| 26 Palmitone           | $(\text{C}_{15}\text{H}_{31})_2 : \text{CO}$  | 450.65          | $\text{C}_{31}\text{H}_{62}\text{O}$             |
| 27 Palmitonitrile      | $\text{C}_{15}\text{H}_{31}\text{CN}$   | 237.34          | $\text{C}_{16}\text{H}_{31}\text{N}$             |
| 28 Parabanic acid      | $\text{C}_3\text{H}_2\text{N}_2\text{O}.\text{H}_2\text{O}$   | 132.07          | $\text{C}_3\text{H}_2\text{O}_3\text{N}_2$       |
| 29 Paraconic acid      | $\text{CH}_2.\text{CH}.\text{COOH}$<br>$\begin{array}{c}   \\ \text{O}.\text{CO}.\text{CH}_2 \end{array}$         | 130.07          | $\text{C}_5\text{H}_6\text{O}_4$                 |

| Density<br>H <sub>2</sub> O=1. | Solubility in      |                                     |                                   | M.P.<br>°C.     | B.P.<br>°C.        |    |
|--------------------------------|--------------------|-------------------------------------|-----------------------------------|-----------------|--------------------|----|
|                                | Water.             | Alcohol.                            | Ether.                            |                 |                    |    |
| 0.94/22°                       |                    |                                     |                                   |                 | 142                | 1  |
| 0.8971/18.8°                   | v.s.s.             |                                     |                                   | liq.            | 146                | 2  |
|                                | m.                 |                                     |                                   | 22.5            | 203—204<br>/714mm. | 3  |
| 1.159/23.5°                    | i.                 | m.                                  | m.                                | liq.            | 131—132<br>/24mm.  | 4  |
| 1.653/18.5°                    | 1: 10.46<br>/14.5° | 1: 2.5, c.                          | 1.266:<br>100/15°                 | 98<br>an. 189.5 |                    | 5  |
| 1.475                          | 1: 23.7/15°        |                                     |                                   |                 |                    | 6  |
| 2.200                          | i.                 |                                     | s. ac.                            |                 |                    | 7  |
| 2.080                          | 1: 3.03/16°        |                                     |                                   |                 |                    | 8  |
|                                | s.s.               |                                     |                                   |                 |                    | 9  |
|                                | 1: 26.21/8°        |                                     |                                   |                 |                    | 10 |
| 1.05/15°                       | i.                 | s.                                  |                                   | liq.            | 206—207            | 11 |
| 1.0793/20°                     | s.s.               | s.                                  |                                   | - 40.6          | 184/740            | 12 |
| 1.1566                         | s.s.               | s.                                  |                                   | 54              | 163.3              | 13 |
|                                | c.i.               | c.s. KOH                            | s. H <sub>2</sub> SO <sub>4</sub> | > 310           |                    | 14 |
|                                | c.v.s.s.           |                                     |                                   | - 12            | 64                 | 15 |
| 0.808/19°                      |                    |                                     |                                   | 114—115         |                    | 16 |
| 1.667                          | h.s.s.             | s. NH <sub>4</sub> OH               |                                   | 417—419         |                    | 17 |
|                                | 1: 58/17°,<br>h.d. | i. (abs.)                           |                                   | d. 210          |                    | 18 |
|                                | h.i.               | h.s.s.                              | i.                                | 245             | 320                | 19 |
|                                | s. alk.            |                                     |                                   | 204—206 d       |                    | 20 |
|                                |                    |                                     |                                   |                 |                    | 21 |
|                                | c.v.s.s.           | warm, s.<br>dil. NH <sub>4</sub> OH |                                   |                 |                    | 22 |
|                                | h.s.               | s.                                  |                                   | 126             |                    | 23 |
| 0.8527/64°                     | i.                 | s.s.                                | v.s.                              | 62.6<br>61.5    | 278/100            | 24 |
|                                |                    |                                     |                                   |                 |                    | 25 |
| 0.7997/82.8°                   |                    |                                     |                                   |                 |                    | 26 |
| 0.8224/31°                     |                    |                                     |                                   | 31              | 251.5/100          | 27 |
|                                | 1: 21/8°           |                                     | i.                                | 242—244 d       |                    | 28 |
|                                | s.                 |                                     |                                   | 57—58           |                    | 29 |

| Name.                                | Formula.  | Formula Empirical Weight. | Formula.  |
|--------------------------------------|---|---------------------------|---|
| 1 Para cyanogen                      | (ON) <sup>6</sup>   | 156.12                    | C <sup>6</sup> N <sup>6</sup>                   |
| 2 — formaldehyde                     | (CH <sub>2</sub> O) <sup>3</sup>  | 60.04                     | C <sup>3</sup> H <sup>6</sup> O <sup>3</sup>    |
| 3 Paralldol                          | (C <sup>4</sup> H <sub>8</sub> O <sub>2</sub> ) <sup>2</sup>  | 176.17                    | C <sup>8</sup> H <sub>16</sub> O <sub>4</sub>   |
| 4 Paraldehyde                        | C <sup>6</sup> H <sub>12</sub> O <sub>3</sub>   | 132.13                    | C <sup>6</sup> H <sub>12</sub> O <sub>3</sub>   |
| 5 Para leucaniline                   | CH(C <sup>6</sup> H <sub>4</sub> .NH <sub>2</sub> ) <sub>3</sub>                                    | 289.28                    | C <sup>19</sup> H <sub>19</sub> N <sub>3</sub>  |
| 6 Param, dicyanogen diamide          | C <sub>2</sub> N <sub>2</sub> (NH <sub>2</sub> ) <sub>2</sub>                                       | 84.10                     | C <sub>2</sub> H <sub>4</sub> N <sub>4</sub>    |
| 7 Para rosaniline                    | O(OH)(C <sup>6</sup> H <sub>4</sub> .NH <sub>2</sub> ) <sub>3</sub>                                 | 305.28                    | C <sub>19</sub> H <sub>19</sub> ON <sub>3</sub> |
| 8 Parvolin, α                        | C <sub>9</sub> H <sub>13</sub> N  | 135.16                    | C <sub>9</sub> H <sub>13</sub> N                |
| 9 —, β                               | C <sup>5</sup> HN(CH <sub>3</sub> ) <sub>4</sub>  | 135.16                    | "   |
| 10 —, 2-methyl-5-propyl pyridine     | C <sup>5</sup> H <sub>3</sub> N(CH <sub>3</sub> ) <sub>4</sub> (C <sub>3</sub> H <sub>7</sub> )     | 135.16                    | "   |
| 11 —, 2: 4-diethyl pyridine          | C <sup>5</sup> H <sub>3</sub> N(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub>                        | 135.16                    | "   |
| 12 —, 3: 5-dimethyl-2-ethyl pyridine | C <sup>5</sup> H <sub>2</sub> N(CH <sub>3</sub> ) <sub>2</sub> (C <sub>2</sub> H <sub>5</sub> )     | 135.16                    | "   |
| 13 —, 2: 5-dimethyl-4-ethyl pyridine | " "   | 135.16                    | "   |
| 14 Pelargonic acid, see              | Nonylic acid  |                           |   |
| 15 Pelargonate, ethyl                | C <sub>9</sub> H <sub>17</sub> O <sub>2</sub> .C <sub>2</sub> H <sub>5</sub>                        | 186.23                    | C <sub>11</sub> H <sub>22</sub> O <sub>2</sub>  |
| 16 Penta acetyl glucose, α           | C <sup>6</sup> H <sub>7</sub> O(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>5</sub>         | 390.26                    | C <sub>16</sub> H <sub>22</sub> O <sub>11</sub> |
| 17 ———, β                            | "   | 390.26                    | "   |
| 18 — amino benzene                   | C <sup>6</sup> H(NH <sub>2</sub> ) <sub>5</sub>   | 153.17                    | C <sup>6</sup> H <sub>11</sub> N <sub>5</sub>   |
| 19 — bromo benzene                   | C <sup>6</sup> HBr  | 472.64                    | C <sup>6</sup> HBr                              |
| 20 — chlor aniline                   | C <sup>6</sup> Cl <sub>5</sub> .NH <sub>2</sub>   | 265.36                    | C <sup>6</sup> H <sub>2</sub> NCl <sub>5</sub>  |
| 21 — — benzene                       | C <sup>6</sup> HCl <sub>5</sub>   | 250.34                    | C <sup>6</sup> HCl <sub>5</sub>                 |
| 22 — — ethane                        | C <sup>6</sup> HCl <sub>5</sub>   | 202.32                    | C <sup>6</sup> HCl <sub>5</sub>                 |
| 23 — erythrite                       | C(CH <sub>2</sub> OH) <sub>4</sub>  | 136.12                    | C <sup>2</sup> H <sub>12</sub> O <sub>4</sub>   |
| 24 — glycol                          | (CH <sub>3</sub> ) <sub>2</sub> C:(CH <sub>2</sub> OH) <sub>2</sub>                                 | 104.12                    | C <sup>5</sup> H <sub>12</sub> O <sub>4</sub>   |
| 25 — methyl amino benzene            | C <sub>6</sub> (CH <sub>3</sub> ) <sub>5</sub> NH <sub>2</sub>                                      | 163.20                    | C <sub>11</sub> H <sub>17</sub> N               |
| 26 — — benzene                       | C <sup>6</sup> H(CH <sub>3</sub> ) <sub>5</sub>   | 148.18                    | C <sub>11</sub> H <sub>16</sub>                 |
| 27 — — ethanol                       | (CH <sub>3</sub> ) <sub>3</sub> C.C(OH)(CH <sub>3</sub> ) <sub>2</sub>                              | 116.16                    | C <sup>7</sup> H <sub>16</sub> O                |
| 28 — — — hydrate                     | 2C <sub>7</sub> H <sub>16</sub> O.H <sub>2</sub> O  | 250.35                    | C <sub>14</sub> H <sub>34</sub> O <sub>3</sub>  |
| 29 — methylene, see                  | Cyclo pentane   |                           |   |
| 30 — — bromide                       | CH <sub>2</sub> Br.(CH <sub>2</sub> ) <sub>3</sub> .CH <sub>2</sub> Br                              | 229.95                    | C <sup>5</sup> H <sub>8</sub> Br <sub>2</sub>   |
| 31 — — diamine, (cadaverine)         | NH <sub>2</sub> .CH <sub>2</sub> .(CH <sub>2</sub> ) <sub>3</sub> .CH <sub>2</sub> .NH <sub>2</sub> | 102.16                    | C <sub>5</sub> H <sub>14</sub> N <sub>2</sub>   |
| 32 — — dicarboxylic acid, 1: 3       | C <sub>5</sub> H <sub>8</sub> (COOH) <sub>2</sub>   | 158.12                    | C <sub>7</sub> H <sub>10</sub> O <sub>4</sub>   |

| Density<br>H <sub>2</sub> O=1. | Solubility in |          |        | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|---------------|----------|--------|-------------|-------------|----|
|                                | Water.        | Alcohol. | Ether. |             |             |    |
|                                | i.            | i.       | s. KOH |             | subl.       | 1  |
|                                | s.            |          |        | 152         |             | 2  |
|                                |               |          |        | 80—90       | 90—100      | 3  |
| 0.998/15°                      | 1:8           |          |        | 12.6        | 124         | 4  |
|                                |               | s.       |        | 148         |             | 5  |
|                                | s.            | s.       | s.s.   | 204         |             | 6  |
|                                | i.            | s.       |        |             |             | 7  |
| 0.986/22°                      |               |          |        | liq.        | 188         | 8  |
|                                |               |          |        | liq.        | 220         | 9  |
| 1.066/0°                       | v.s.          | s.       | s.     | liq.        | >200        | 10 |
| 0.9338/0°                      | s.s.          |          |        | liq.        | 187—188     | 11 |
| 0.9418/0°                      |               |          |        | liq.        | 198—200     | 12 |
| 0.916/14°                      | 1:76/0°       |          |        | liq.        | 186         | 13 |
|                                |               |          |        |             |             | 14 |
| 0.8655/17.5°                   |               | s.       |        | liq.        |             | 15 |
|                                |               |          |        | 111—112     |             | 16 |
|                                |               |          |        | 127—128     |             | 17 |
|                                | v.s.          | i.       | i.     |             |             | 18 |
|                                |               | s.       |        | 158         |             | 19 |
|                                |               | s.       | s.     | 232         |             | 20 |
| 1.8342/16.5°                   |               |          |        | 85—86       | 275—277     | 21 |
| 1.709/0°                       |               |          |        | <—18        | 160.5       | 22 |
|                                |               |          |        | 253         |             | 23 |
|                                | s.            |          |        | 129         | 206/747mm   | 24 |
|                                | i.            | s.       | s.     | 151—152     | 277—278     | 25 |
|                                |               |          |        |             |             | 26 |
|                                |               |          |        | 53          | 230         | 26 |
|                                |               |          |        | 17          | 131         | 27 |
|                                | s.s.          |          |        | 33          |             | 28 |
|                                |               |          |        |             |             | 29 |
|                                |               |          |        | —34.5       | 204—206     | 30 |
| 0.8846/15°                     | s.            | s.       | s.s.   |             | 178—179     | 31 |
|                                |               |          |        | 121         | 214         | 32 |

| Name.                                   | Formula.                      | Formula Empirical<br>Weight. Formula. |
|---|-------------------------------|---------------------------------------|
| 1 Penta methyl phenol                   | $C_6OH(CH_3)_5$               | 164.18 $C_{11}H_{16}O$                |
| 2 — — rosaniline                        | $C_{24}H_{29}N_3O$            | 375.38 $C_{24}H_{29}O_3N$             |
| 3 Pentadiene, see<br>Piperylene         |                               |                                       |
| 4 Pentane, norm.                        | $CH_3.(CH_2)_3.CH_3$          | 72.12 $C_5H_{12}$                     |
| 5 —, sec.                               | $(CH_3)_2:CH.CH_2.CH_3$       | 72.12 „                               |
| 6 —, tert.                              | $C(CH_3)_4$                   | 72.12 „                               |
| 7 Pentahydroxy pentane                  | $C_5H_7(OH)_5$                | 152.12 $C_5H_{12}O_5$                 |
| 8 Per chlor ether                       | $C_4Cl_4O$                    | 418.62 $C_4OCl_{10}$                  |
| 9 — — ethylene                          | $CCl_2:CCl_2$                 | 165.85 $C_2Cl_4$                      |
| 10 — — methyl<br>mercaptan              | $CCl_3.SCl$                   | 185.90 $CCl_4S$                       |
| 11 — thiocyanic acid                    | $C_2N_2H_2S_3$                | 150.23 $C_2H_2N_2S_3$                 |
| 12 Phellandrene                         | $C_{10}H_{16}$                | 136.18 $C_{10}H_{16}$                 |
| 13 Phenacetin                           | $C_6H_4(OC_2H_5)NH.CO.CH_3$   | 179.16 $C_{10}H_{13}O_2N$             |
| 14 Phenanthra hydro-<br>quinone, 9 : 10 | $C_{14}H_8(OH)_2$             | 210.15 $C_{14}H_{10}O_2$              |
| 15 Phenanthra quinone                   | $C_{14}H_8O_2 (9 : 10)$       | 208.13 $C_{14}H_8O_2$                 |
| 16 Phenanthrene                         | $C_{14}H_{10}$                | 178.15 $C_{14}H_{10}$                 |
| 17 Phenanthron, 9                       | $C_{14}H_9(OH)$               | 192.15 $C_{14}H_{11}O$                |
| 18 Phenazine                            | $C_{12}H_8:N.N:C_6H_4$        | 180.14 $C_{12}H_8N_2$                 |
| 19 Phenethylamine, $\beta$              | $C_6H_5.CH_2.CH_2.NH_2$       | 121.14 $C_8H_{11}N$                   |
| 20 —, $\alpha$                          | $C_6H_5.CH(NH_2).CH_3$        | 121.14 „                              |
| 21 Phenetidine, $\phi$                  | $C_2H_5O.C_6H_4.NH_2$         | 137.14 $C_8H_{11}ON$                  |
| 22 —, $m$                               | „ „                           | 137.14 „                              |
| 23 —, $p$                               | „ „                           | 137.14 „                              |
| 24 Phenetol                             | $C_2H_5.O.C_6H_5$             | 122.12 $C_8H_{10}O$                   |
| 25 Phenol                               | $C_6H_5OH$                    | 94.08 $C_6H_6O$                       |
| 26 — phthalein                          | $(C_6H_4OH)_2:C(COO):C_6H_4$  | 318.21 $C_{26}H_{14}O_4$              |
| 27 — phthaline                          | $(C_6H_4OH)_2:CH.C_6H_4.COOH$ | 320.23 $C_{20}H_{16}O_4$              |
| 28 — sulphonic acid, $o$                | $C_6H_4OH.SO_3H$              | 174.14 $C_6H_6O_4S$                   |
| 29 — — —, $m$                           | „ „ $.2H_2O$                  | 210.17 „                              |
| 30 — — —, $p$                           | „ „                           | 174.14 „                              |

| Density<br>H <sub>2</sub> O=1. | Solubility in |              |  | M.P.<br>°C.                 | B.P.<br>°C. |    |
|--------------------------------|---------------|--------------|--|-----------------------------|-------------|----|
|                                | Water.        | Alcohol.     | Ether                                  |                             |             |    |
|                                | i.            | s.           | i.                                     | 125                         | 267         | 1  |
|                                |               |              |  | 130                         |             | 2  |
|                                |               |              |  |                             |             | 3  |
| 0.6337/15                      |               |              |  | liq.                        | 36.15       | 4  |
| 0.6382/14°                     |               |              |  | liq.                        | 27.95       | 5  |
|                                |               |              |  |                             | 9.5         | 6  |
|                                |               |              |  | 102                         |             | 7  |
| 1.19/14.5°                     |               |              |  | 69                          | d.          | 8  |
| 1.619/20°                      |               |              |  |                             | 119.5—120.5 | 9  |
|                                |               |              |  |                             | /747.3mm.   |    |
| 1.712/12.8°                    | i.            |              |  |                             | 146.5—148   | 10 |
|                                | 1:100         | s.           | s., s. CHCl <sub>3</sub>               |                             |             | 11 |
| 0.8558/10°                     |               | i.           | s.                                     |                             | 175—176     | 12 |
|                                |               |              |  |                             | /755mm.     |    |
|                                | 1:70, h.      | s.           |  | 135                         |             | 13 |
|                                | h.s.          | v.s.         | v.s.                                   | 145—147                     |             | 14 |
| 1.404                          | h.s.s.        | s.s.         | s.s., s. C <sub>6</sub> H <sub>6</sub> | 205                         | >360        | 15 |
| 1.063/100°                     | i.            | 2.62:100/16° | s.                                     | 99—99.5,<br>subl. 95—<br>96 | 340         | 16 |
|                                | s.            | v.s.         | v.s.                                   | 148—149                     |             | 17 |
|                                | v.s.s.        | h.s.         | s.                                     | 171                         | >360        | 18 |
| 0.9580/24°                     | s.            | s.           | s.                                     | liq.                        | 198         | 19 |
| 0.9395/15°                     | 1:24/20°      |              |  | liq.                        | 183—185     | 20 |
|                                |               | s.           |  | liq.                        | 228         | 21 |
|                                |               | s.           |  | liq.                        | 180—205     | 22 |
|                                |               |              |  |                             | /100mm.     |    |
|                                |               | s.           |  | 2.4                         | 244         | 23 |
| 0.9702/15°                     |               | s.           |  | - 34                        | 171         | 24 |
| 1.0489/50°                     | 5.1:100/25°   | m.           | m.                                     | 42.5—43                     | 181         | 25 |
|                                | h.s.s.        | h.s.         | s.                                     | 253—255,<br>amorph. 100     |             | 26 |
|                                |               |              |  | 225                         |             | 27 |
|                                | s.            |              |  |                             |             | 28 |
|                                | v.s.          | v.s.         |  |                             |             | 29 |
|                                | s.            | s.           |  |                             |             | 30 |
|                                | s.            | s.           |  |                             |             |    |

| Name.   | Formula.  | Formula Weight. | Empirical Formula. |
|---|---|-----------------|--------------------|
| 1 Phenol tricarboxylic acid, 5 : 1 : 2 : 4      | $C_6H_2OH(COOH)_3$  | 226.09          | $C_9H_6O_7$        |
| 2 ———, 2 : 1 : 3 : 5                            | "   | 226.09          | "                  |
| 3 Phenoquinone                                  | $C_6H_4O_2 \cdot 2C_6H_6O$  | 296.22          | $C_{18}H_6O_4$     |
| 4 Phenoxazine                                   | $C_6H_4 \begin{array}{c} \diagup \text{NH} \diagdown \\ \diagdown \text{O} \diagup \end{array} C_6H_4$                | 183.14          | $C_{12}H_9ON$      |
| 5 Phenthiazine, thio-diphenylamine              | $C_6H_4 \begin{array}{c} \diagup \text{NH} \diagdown \\ \diagdown \text{S} \diagup \end{array} C_6H_4$                | 199.20          | $C_{12}H_9NS$      |
| 6 Phenyl acetaldehyde                           | $C_6H_5 \cdot CH_2 \cdot CHO$   | 120.10          | $C_8H_8O$          |
| 7 — acetic acid                                 | $C_6H_5 \cdot CH_2 \cdot COOH$  | 136.10          | $C_8H_8O_2$        |
| 8 — acetate, ethyl                              | $C_6H_5 \cdot CH_2 \cdot COOC_2H_5$   | 164.15          | $C_{10}H_{12}O_2$  |
| 9 —, methyl                                     | $C_6H_5 \cdot CH_2 \cdot COOCH_3$   | 150.12          | $C_9H_{10}O_2$     |
| 10 — acetic anhydride                           | $(C_6H_5 \cdot CH_2 \cdot CO)_2 : O$  | 254.19          | $C_{16}H_{14}O_3$  |
| 11 — acetyl chloride                            | $C_6H_5 \cdot CH_2 \cdot COCl$  | 154.56          | $C_8H_7OCl$        |
| 12 — acetylene                                  | $C_6H_5 \cdot C : CH$   | 102.19          | $C_8H_6$           |
| 13 — acridine, 9                                | $C_6H_4 \begin{array}{c} \diagup \text{N} \diagdown \\ \diagdown \text{C} \diagup \end{array} C_6H_4 \text{—} C_6H_5$ | 255.21          | $C_{19}H_{13}N$    |
| 14 — amino ethyl alcohol                        | $C_6H_5 \cdot NH \cdot (C_2H_4OH)$  | 137.14          | $C_8H_{11}ON$      |
| 15 — — propionic acid, $\beta$ $\alpha$ , rac.  | $C_6H_5 \cdot CH_2 \cdot CH(NH_2)COOH$  | 165.14          | $C_9H_{11}O_2N$    |
| 16 — — —, $\beta \beta$                         | $C_6H_5 \cdot CH(NH_2) \cdot CH_2 \cdot COOH$   | 165.14          | "                  |
| 17 — angelic acid                               | $C_6H_5 \cdot CH : C(C_2H_5)COOH$   | 176.15          | $C_{11}H_{12}O_2$  |
| 18 — anthracene, 9                              | $C_{14}H_9 \cdot C_6H_5$  | 254.21          | $C_{20}H_{14}$     |
| 19 — benzene, see Diphenyl                      | Diphenyl  |                 |                    |
| 20 — benzoic acid, see Diphenyl carboxylic acid | Diphenyl carboxylic acid  |                 |                    |
| 21 — butyric acid, $\alpha$                     | $C_6H_5(CH_2)_3COOH$  | 164.12          | $C_{10}H_{12}O_2$  |
| 22 — —, $\beta$ , $d$                           | $CH_3 \cdot CH(C_6H_5) \cdot CH_2 \cdot COOH$   | 164.12          | "                  |
| 23 — —, $\beta$ , $l$                           | " "   | 164.12          | "                  |
| 24 — —, $\beta$ , $r$                           | " "   | 164.12          | "                  |
| 25 — carbylamine                                | $C_6H_5 \cdot NC$   | 103.09          | $C_7H_5N$          |
| 26 — cinnamic acid, $\alpha$                    | $C_6H_5 \cdot CH : C(C_6H_5)COOH$   | 224.17          | $C_{15}H_{12}O_2$  |
| 27 — —, $\beta$                                 | $C_6H_5 \cdot C(C_6H_5) : CH \cdot COOH$  | 224.17          | "                  |
| 28 — crotonic acid                              | $C_6H_5 \cdot CH : C(CH_3)COOH$   | 162.13          | $C_{10}H_{10}O_2$  |
| 29 — cyanamide                                  | $NC \cdot NH \cdot C_6H_5$  | 106.10          | $C_7H_6N_2$        |
| 30 — <i>iso</i> -cyanate                        | $C_6H_5 \cdot N : C : O$  | 119.08          | $C_7H_5ON$         |



| Density<br>H <sub>2</sub> O=1. | Solubility in                    |          |        | M.P.<br>°C. | B.P.<br>°C.        |    |
|--------------------------------|----------------------------------|----------|--------|-------------|--------------------|----|
|                                | Water.                           | Alcohol. | Ether. |             |                    |    |
|                                | 1 : 200/10°                      | h.s.     | s.s.   | an. 245 d.  |                    | 1  |
|                                |                                  |          |        | 312 d       |                    | 2  |
|                                | c.s.                             | s.       | s.     | 71          |                    | 3  |
|                                |                                  | v.s.     | v.s.   | 148         |                    | 4  |
|                                | s. C <sub>6</sub> H <sub>6</sub> | c.s.s.   | s.     | 180—181     | 371                | 5  |
| 1.085                          |                                  |          |        | liq.        | 205—207            | 6  |
| 1.0809/80°                     | h.s.                             | s.       | v.     | 77.5—78     | 262—263<br>/751mm. | 7  |
| 1.0462/15°                     |                                  |          |        |             | 229                | 8  |
| 1.044/16°                      |                                  |          |        |             | 214—216/754mm      | 9  |
|                                |                                  |          | s.     | 72.5        |                    | 10 |
| 1.1753/15°                     |                                  |          |        | liq.        | 180—183 d          | 11 |
| 0.9295/20°                     |                                  |          |        |             | 141.6              | 12 |
|                                | s. C <sub>6</sub> H <sub>6</sub> | h.s.     | s.     | 181—183     | 403—404            | 13 |
| 1.11/0°                        | v.s.s.                           | s.       |        | liq.        | 280                | 14 |
|                                | c.s.s.                           | h.v.s.s. | i.     | 263         |                    | 15 |
|                                | c.s.s.                           | s.s.     | i.     | 234—235     |                    | 16 |
|                                | o.v.s.s.                         | s        |        | 104         |                    | 17 |
|                                | s. C <sub>6</sub> H <sub>6</sub> | h.s.     | s.     | 152—153     | 417                | 18 |
|                                |                                  |          |        |             |                    | 19 |
|                                |                                  |          |        |             |                    | 20 |
|                                | h.s.                             | s.       | s.     | 42          | 270—272            | 21 |
|                                |                                  |          |        |             | 155.5—156          | 22 |
|                                |                                  |          |        |             | 157.2—157.7        | 23 |
|                                |                                  |          |        | 47          | 270                | 24 |
| 0.9775/15°                     |                                  |          |        |             | 165—166 d.         | 25 |
|                                | c.s.s.                           | s.       | s.     | 169—170     | subl.              | 26 |
|                                |                                  |          |        | 159—161     |                    | 27 |
|                                | s. C <sub>6</sub> H <sub>6</sub> | s.       | s.     | 74          | 288                | 28 |
|                                | s.s.                             | s.       | s.     | 47          |                    | 29 |
| 1.092/15°                      |                                  |          |        |             | 163                | 30 |

| Name.                           | Formula.   | Formula Weight. | Empirical Formula.   |
|---------------------------------|--|-----------------|----------------------|
| 1 Phenyl dihydroquinazoline     | $C_6H_4 \begin{cases} CH_2.N.C_6H_5 \\ N:OH \end{cases}$ | 208.19          | $C_{14}H_{12}N_2$    |
| 2 — disulphide                  | $C_6H_5)_2S$   | 218.26          | $C_{12}H_{10}S_2$    |
| 3 — di tolyl methane            | $(CH_3.C_6H_4)_2:CH.C_6H_5$                              | 272.27          | $C_{21}H_{20}$       |
| 4 — ether                       | $C_6H_5.O.C_6H_5$  | 170.14          | $C_{12}H_{10}O$      |
| 5 — ethyl alcohol, norm.        | $C_6H_5.CH_2.CH_2OH$                                     | 122.12          | $C_8H_{10}O$         |
| 6 — —, sec                      | $C_6H_5.CHOH.CH_3$                                       | 122.12          | "                    |
| 7 — formanilide                 | $C_6H_5N(C_6H_5)COH$                                     | 197.16          | $C_{13}H_{11}ON$     |
| 8 — glucosazone, $\beta$        | $C_{18}H_{22}N_4O_4$                                     | 358.31          | $C_{18}H_{22}O_4N_4$ |
| 9 — —, $\alpha$                 | "  | 358.31          | "                    |
| 10 — glycine                    | $C_6H_5.NH.CH_2.COOH$                                    | 151.12          | $C_8H_9O_2N$         |
| 11 — — carboxylic acid          | $COOH.C_6H_5.NH.CH_2.COOH$                               | 195.13          | $C_9H_9O_4N$         |
| 12 — hydrazine                  | $C_6H_5.NH.NH_2.H_2O$                                    | 117.12          | $C_6H_8N_2$          |
| 13 — hydroxylamine, $\beta$     | $C_6H_5.NH.OH$   | 109.10          | $C_6H_7ON$           |
| 14 — isoamyl ether              | $C_6H_5.O.C_5H_{11}$                                     | 164.18          | $C_{11}H_{16}O$      |
| 15 — isocrotonic acid           | $C_6H_5.CH:CH.CH_2.COOH$                                 | 162.13          | $C_{10}H_{10}O_2$    |
| 16 — isopropyl ketone           | $C_6H_5.CO.CH:(CH_3)_2$                                  | 148.15          | $C_{10}H_{12}O$      |
| 17 — lactic acid, $\alpha$      | $C_6H_5.CH_2.CHOH.COOH$                                  | 166.13          | $C_9H_{10}O_3$       |
| 18 — — —, $\beta$               | $C_6H_5.CHOH.CH_2.COOH$                                  | 166.13          | "                    |
| 19 — malonic acid               | $C_6H_5.CH:(COOH)_2$                                     | 180.11          | $C_8H_8O_4$          |
| 20 — malonate, diethyl          | $C_6H_5.CH:(COOC_2H_5)_2$                                | 236.19          | $C_{13}H_{16}O_4$    |
| 21 — mercaptan                  | $C_6H_5.SH$  | 110.14          | $C_6H_8S$            |
| 22 — methyl pyrazolone          | $C_{10}H_{10}N_2O$                                       | 174.15          | $C_{10}H_{10}ON_2$   |
| 23 — naphthalene, $\alpha$      | $C_{10}H_5.C_{10}H_7$                                    | 204.18          | $C_{16}H_{12}$       |
| 24 — —, $\beta$                 | "  | 204.18          | "                    |
| 25 — naphthylamine, $\alpha$    | $C_{10}H_7.NH.C_6H_5$                                    | 219.19          | $C_{16}H_{13}N$      |
| 26 — —, $\beta$                 | "  | 219.19          | "                    |
| 27 — nitramine                  | $C_6H_5.NH.NO_2$   | 138.10          | $C_6H_5O_2N_2$       |
| 28 — oxycrotonic acid, $\alpha$ | $C_6H_5.CH:CH.CHOH.COOH$                                 | 178.13          | $C_{10}H_{10}O_3$    |
| 29 — oxydisulphide              | $(C_6H_5)_2S_2O_2$                                       | 250.26          | $C_{12}H_{10}O_2S_2$ |
| 30 — phosphine                  | $C_6H_5.PH_2$  | 110.13          | $C_6H_7P$            |
| 31 — phosphinic acid            | $C_6H_5.PO(OH)_2$  | 158.13          | $C_6H_7O_3P$         |
| 32 — propiolic acid, $\delta$   | $C_6H_5O$  | 146.09          | $C_9H_6O_2$          |
| 33 — propyl alcohol, $\alpha$   | $C_6H_5.CH_2.CH_2.CH_2OH$                                | 136.14          | $C_9H_{12}O$         |
| 34 — — —, $\beta$               | $C_6H_5.CH_2.CHOH.CH_2$                                  | 136.14          | "                    |
| 35 — — —, $\gamma$              | $C_6H_5.CHOH.CH_2.CH_3$                                  | 136.14          | "                    |
| 36 — — ketone                   | $C_6H_5.CO.C_3H_7$                                       | 136.14          | $C_9H_{12}O$         |

| Density<br>$H_2O=1.$ | Solubility in |             |             | M.P.<br>°C. | B.P.<br>°C.       |    |
|----------------------|---------------|-------------|-------------|-------------|-------------------|----|
|                      | Water.        | Alcohol.    | Ether.      |             |                   |    |
|                      | i.            | s.          | s.          | 93          |                   | 1  |
|                      | i.            | s.          | v.s.        | 60—61       | 310               | 2  |
|                      | v.s. $CHCl_3$ | v.s. $CS_2$ | v.s., v.s.  | 53          |                   | 3  |
|                      | i.            | s.          | s. $C_6H_6$ | 28          | 257               | 4  |
| 1.0337/21°           |               | s. (dil.)   |             | liq.        | 212               | 5  |
| 1.013                | i.            |             |             | liq.        | 202—204           | 6  |
|                      |               | s.          |             | 73—74       | 210—220<br>in vac | 7  |
|                      | v.s.s.        | h.v.s.      |             | 205         |                   | 8  |
|                      |               |             |             | 145         |                   | 9  |
|                      | s.            | s.s.        | v.s.s.      | 126—127     |                   | 10 |
|                      | h.s.          | s.          | s.          | 207 d.      |                   | 11 |
| 1.0981/20°           | h.s.          | m.          | m.          | 19.6        | 243.5             | 12 |
|                      | 1 : 10, h.    | v.s.        | v.s.        | 80—81       |                   | 13 |
| 0.9198/21°           |               |             |             | liq.        | 215               | 14 |
|                      | h.s.s.        | v.s.        | v.s.        | 86          | 302               | 15 |
|                      |               |             |             |             | 220/746mm         | 16 |
|                      | s.            |             |             | 97—98       |                   | 17 |
|                      | s.v.s., h.m.  |             |             | 93          |                   | 18 |
|                      | s.s.          | s.s.        | s.s.        | 152—153     |                   | 19 |
|                      |               |             |             |             | 285 d.            | 20 |
| 1.078/24°            | i.            | s.          | s.          | liq.        | 172.5             | 21 |
|                      | h.s.          | h.s.        | v.s.s.      | 127         | 287/205mm         | 22 |
|                      | s. $C_6H_6$   | s.          | s.          | 0           | 324—325           | 23 |
|                      | s. $C_6H_6$   | h.s.        |             | 102—102.5   | 345—346           | 24 |
|                      | s. $CH_3OH$   | s.          | s.          | 62          | 335/258mm         | 25 |
|                      | s. $CH_3OH$   | s.          | s.          | 107.5—108   | 395—395.5         | 26 |
|                      |               |             |             | 46          | 98                | 27 |
|                      | s. $C_6H_6$   | s.          | s.          | 137         |                   | 28 |
|                      |               | h.s.        | s.          | 45          |                   | 29 |
| 1.001/15°            |               |             |             |             | 160—161           | 30 |
| 1.475                | 23.5 : 100/   | s.          |             | 158         |                   | 31 |
|                      | h.s. 15°      | v.s.        | v.s.        | 136—137     |                   | 32 |
| 1.008/18°            | s.s.          | m.          | m.          | liq.        | 212               | 33 |
|                      |               |             |             |             | 214.5—215.5       | 34 |
|                      |               |             |             | liq.        | 235               | 35 |
| 0.990/15°            |               |             |             | liq.        | 220—222           | 36 |

| Name.                                | Formula.                 | Formula Weight. | Empirical Formula. |
|--------------------------------------|--------------------------|-----------------|--------------------|
| 1 Phenyl pyridine, $\alpha$          | $C_5H_4N.C_6H_5$         | 155.14          | $C_{11}H_9N$       |
| 2 —, $\beta$                         | „ „                      | 155.14          | „                  |
| 3 —, $\gamma$                        | „ „                      | 155.14          | „                  |
| 4 —quinoline, 2                      | $C_9H_6N.C_6H_5$         | 205.17          | $C_{15}H_{11}N$    |
| 5 —, 3                               | „ „                      | 205.17          | „                  |
| 6 —, 4                               | „ „                      | 205.17          | „                  |
| 7 —, 6                               | „ „                      | 205.17          | „                  |
| 8 —, 8                               | „ „                      | 205.17          | „                  |
| 9 —salicylic acid                    | $C_6H_5.C_6H_3(OH)COOH$  | 214.15          | $C_{13}H_{10}O_3$  |
| 10 —sulphide                         | $(C_6H_5)_2S$            | 186.20          | $C_{12}H_{10}S$    |
| 11 —thiocyanate, <i>iso</i> .        | $C_6H_5NCS$              | 135.15          | $C_7H_5NS$         |
| 12 —thioglycollic acid               | $C_6H_5.S.CH_2COOH$      | 169.16          | $C_8H_8O_2S$       |
| 13 —thiourea                         | $CS(NH_2)NH.C_6H_5$      | 152.18          | $C_7H_8N_2S$       |
| 14 —tolyl                            | $C_6H_5.C_6H_4.CH_3$     | 168.16          | $C_{13}H_{12}$     |
| 15 —ketone, <i>o</i>                 | $C_6H_5.CO.C_6H_4.CH_3$  | 196.17          | $C_{14}H_{12}O$    |
| 16 —, <i>m</i>                       | „ „                      | 196.17          | „                  |
| 17 —, <i>p</i>                       | „ „                      | 196.17          | „                  |
| 18 —urethane                         | $C_6H_5.NH.COOC_2H_5$    | 165.14          | $C_9H_{11}O_2N$    |
| 19 Phenylene diacetic acid, <i>o</i> | $C_6H_4:(CH_2.COOH)_2$   | 194.13          | $C_{10}H_{10}O_4$  |
| 20 —, <i>m</i>                       | „ „                      | 194.13          | „                  |
| 21 —, <i>p</i>                       | „ „                      | 194.13          | „                  |
| 22 —diamine, <i>o</i>                | $C_6H_4(NH_2)_2$         | 108.11          | $C_6H_8N_2$        |
| 23 —, <i>m</i>                       | „ „                      | 108.11          | „                  |
| 24 —, <i>p</i>                       | „ „                      | 108.11          | „                  |
| 25 —mercaptan, 1:3                   | $C_6H_4(SH)_2$           | 142.20          | $C_6H_6S_2$        |
| 26 —, 1:4                            | „ „                      | 142.20          | „                  |
| 27 Phloretic acid                    | $C_9H_4OH.CH(CH_3).COOH$ | 166.13          | $C_9H_{10}O_3$     |
| 28 Phloretin                         | $C_{15}H_{14}O$          | 274.19          | $C_{15}H_{14}O$    |
| 29 Phloridzin                        | $C_{21}H_{24}O_5.2H_2O$  | 472.33          | $C_{21}H_{24}O_5$  |
| 30 Phloroglucinol, 1:3:5             | $C_6H_3(OH)_3.2H_2O$     | 162.11          | $C_6H_6O_3$        |
| 31 —tricarboxylic ester              | $C_9H_3O(C_2H_5)_3$      | 342.22          | $C_{15}H_{18}O_9$  |
| 32 —triethyl ether, 1:3:5            | $C_6H_3(OC_2H_5)_3$      | 210.22          | $C_{12}H_{18}O_3$  |
| 33 —trioxime                         | $C_6H_6(NO)_3$           | 171.13          | $C_6H_9O_3N_3$     |
| 34 Phlorel                           | $C_2H_5.C_6H_4OH$        | 122.12          | $C_8H_{10}O$       |

| Density<br>$H_2O=1.$ | Solubility in |               |                          | M.P.<br>°C. | B.P.<br>°C.            |    |
|----------------------|---------------|---------------|--------------------------|-------------|------------------------|----|
|                      | Water.        | Alcohol.      | Ether.                   |             |                        |    |
| $>H_2O$              | i.            |               |                          | liq.        | 268.5—270.5<br>/749mm. | 1  |
| $>H_2O$              | i.            | s.            | s.                       | oil.        | 269—270<br>/749mm.     | 2  |
|                      | h.s.          |               |                          | 77—78       | 274—275                | 3  |
|                      | s. $C_6H_6$   | s.            | s.                       | 83—84       | 363                    | 4  |
|                      | v.s.s.        | s.            | s.                       | 52          |                        | 5  |
|                      | s.s.          | h.s.          | s.                       | 61—62       |                        | 6  |
| 1.194/20°            |               |               |                          | 110—111     | 260/77mm               | 7  |
|                      |               |               |                          |             | 283/187                | 8  |
|                      |               | s.s. $CHCl_3$ |                          | 159         |                        | 9  |
| 1.12                 | i.            | s.            | s.                       |             | 296                    | 10 |
| 1.135/15°            | i.            | s. (abs.)     | s.                       | — 21        | 218.5                  | 11 |
|                      | c.s.s.; h.s.  | m.            | m.                       | 62          |                        | 12 |
|                      | 1: 400, o.    | 5.6: 100      | s. alk                   | 154         |                        | 13 |
|                      | 1: 17, h.     | /17°          |                          |             |                        |    |
| 1.015/27°            |               |               |                          | 27          | 261—262                | 14 |
|                      |               |               |                          | liq.        | 315—316                | 15 |
| 1.088/17.5°          | m. $C_6H_6$   | m             | m.                       | liq.        | 314—316                | 16 |
|                      | s. $C_6H_6$   | c.s.          | s.                       | 60          | 322                    | 17 |
|                      |               |               |                          | 51—52       | 237—238                | 18 |
|                      | c.s.s.        | s.            | s.                       | 150         |                        | 19 |
|                      | s.            | s.            | s.                       | 170         |                        | 20 |
|                      | h.s.          | s.            | s.                       | 244         |                        | 21 |
|                      | h.s.          | v.s.          | v.s.,<br>s. $CHCl_3$     | 102—103     | 256—258                | 22 |
| 1.1389/15°           | v.s.          | v.s.          | v.s.                     | 61          | 282—284                | 23 |
|                      | s.            | s.            | s.                       | 140         | 267                    | 24 |
|                      |               |               |                          | 27          | 243                    | 25 |
|                      |               |               |                          | 98          |                        | 26 |
|                      | h.s.          | s.            | s.                       | 128—129     |                        | 27 |
|                      | h.v.s.s.      | h.m. acetic.  | v.s.s.                   | 253—255 d   |                        | 28 |
| 1.4298/19°           | h.s.          | s.            | i.                       | 108         |                        | 29 |
|                      | s.            | s.            | s.                       | an. 217—219 |                        | 30 |
|                      | i.            | s.s.          | s.                       | 104         |                        | 31 |
|                      | i.            | v.s.          | v.s.                     | 43          | 175/24mm.              | 32 |
|                      | v.s.s.        | v.s.s.        | s. $CHCl_3$ ,<br>acetone | d 140       |                        | 33 |
| 1.0371/0°            |               |               |                          | liq.        | 206.5—207.5            | 34 |

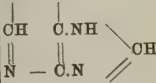
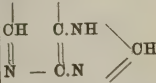
| Name.                             | Formula.   | Formula Weight. | Empirical Formula.                               |
|-----------------------------------|--|-----------------|--|
| 1 Phorone                         | $(\text{CH}_3)_2 : \text{C} : \text{CH} . \text{CO} . \text{OH} : \text{C} : (\text{OH}_3)_2$    | 138.16          | $\text{C}_9 \text{H}_{14} \text{O}$              |
| 2 Phosgene                        | $\text{COCl}_2$  | 98.93           | $\text{COCl}_2$                                  |
| 3 Phosphenyl chloride             | $\text{C}_6 \text{H}_5 . \text{PCl}_2$   | 179.03          | $\text{C}_6 \text{H}_5 \text{Cl}_2 \text{P}$     |
| 4 Phosphenylic acid               | $\text{C}_6 \text{H}_5 . \text{PO}(\text{OH})_2$   | 142.13          | $\text{C}_6 \text{H}_7 \text{O}_2 \text{P}$      |
| 5 Phospho benzene                 | $\text{C}_6 \text{H}_5 . \text{P} : \text{P} . \text{C}_6 \text{H}_5$                            | 216.22          | $\text{C}_{12} \text{H}_{10} \text{P}_2$         |
| 6 Phthalamide                     | $\text{C}_6 \text{H}_4 : (\text{CONH}_2)_2$  | 164.12          | $\text{C}_8 \text{H}_8 \text{O}_2 \text{N}_2$    |
| 7 Phthalanil, <i>sym.</i>         | $\text{C}_8 \text{H}_4 \text{O}_2 : \text{N} . \text{C}_6 \text{H}_5$                            | 223.15          | $\text{C}_{14} \text{H}_9 \text{O}_2 \text{N}_2$ |
| 8 —, <i>asym.</i>                 | " "  | 223.15          | " "  |
| 9 Phthalic acid, <i>o</i>         | $\text{C}_6 \text{H}_4 : (\text{COOH})_2$  | 166.09          | $\text{C}_8 \text{H}_6 \text{O}_4$               |
| 10 Phthalate, ethyl hydrogen      | $\text{C}_6 \text{H}_4 (\text{COOC}_2 \text{H}_5) \text{COOH}$                                   | 194.13          | $\text{C}_{10} \text{H}_{10} \text{O}_4$         |
| 11 —, diethyl                     | $\text{C}_6 \text{H}_4 : (\text{COOC}_2 \text{H}_5)_2$   | 222.17          | $\text{C}_{12} \text{H}_{14} \text{O}_4$         |
| 12 Phthalic acid, <i>m., iso.</i> | $\text{C}_6 \text{H}_4 : (\text{COOH})_2$  | 166.09          | $\text{C}_8 \text{H}_6 \text{O}_4$               |
| 13 —, <i>p, tere.</i>             | " "  | 166.09          | " "  |
| 14 — aldehyde                     | $\text{C}_8 \text{H}_4 : (\text{CHO})_2$   | 134.09          | $\text{C}_8 \text{H}_6 \text{O}_2$               |
| 15 —, <i>iso.</i>                 | " "  | 134.09          | " "  |
| 16 —, <i>tere.</i>                | " "  | 134.09          | " "  |
| 17 — anhydride                    | $\text{C}_6 \text{H}_4 : (\text{CO})_2 : \text{O}$   | 148.07          | $\text{C}_8 \text{H}_4 \text{O}_3$               |
| 18 Phthalide                      | $\text{C}_6 \text{H}_4 : (\text{CH}_2)(\text{CO}) : \text{O}$                                    | 134.09          | $\text{C}_8 \text{H}_6 \text{O}_2$               |
| 19 Phthalimide                    | $\text{C}_6 \text{H}_4 : (\text{CO})_2 : \text{NH}$  | 147.09          | $\text{C}_8 \text{H}_5 \text{O}_2 \text{N}$      |
| 20 Phthalonic acid                | $\text{COOH} . \text{C}_6 \text{H}_4 . \text{CO} . \text{COOH} . 2\text{H}_2 \text{O}$           | 230.12          | $\text{C}_9 \text{H}_6 \text{O}_5$               |
| 21 Phthalonitrile, <i>iso.</i>    | $\text{C}_6 \text{H}_4 : (\text{CN})_2$  | 128.09          | $\text{C}_8 \text{H}_4 \text{N}_2$               |
| 22 —, <i>tere.</i>                | " "  | 128.09          | " "  |
| 23 Phthalophenone                 | $(\text{C}_6 \text{H}_5)_2 : \text{C} . \text{O} . \text{C}_6 \text{H}_4 . \text{CO} . \text{O}$ | 286.21          | $\text{C}_{20} \text{H}_{14} \text{O}_2$         |
| 24 Phthalyl chloride, <i>o</i>    | $\text{C}_6 \text{H}_4 : (\text{COCl})_2$  | 202.99          | $\text{C}_8 \text{H}_4 \text{O}_2 \text{Cl}_2$   |
| 25 —, <i>m</i>                    | " "  | 202.99          | " "  |
| 26 —, <i>p</i>                    | " "  | 202.99          | " "  |
| 27 Physetoleic acid, see          | Hypogæic acid  |                 |  |
| 28 Picoline, 2                    | $\text{C}_5 \text{H}_4 \text{N} . \text{CH}_3$   | 93.10           | $\text{C}_6 \text{H}_7 \text{N}$                 |
| 29 —, 3                           | " "  | 93.10           | " "  |
| 30 —, 4                           | " "  | 93.10           | " "  |
| 31 Picolinic acid                 | $\text{C}_5 \text{H}_4 \text{N} . \text{COOH}$   | 123.08          | $\text{C}_6 \text{H}_5 \text{O}_2 \text{N}$      |
| 32 Picramide, trinitro aniline    | $\text{C}_6 \text{H}_2 (\text{NO}_2)_3 \text{NH}_2$  | 228.10          | $\text{C}_6 \text{H}_4 \text{O}_6 \text{N}_4$    |
| 33 Picramic acid                  | $\text{C}_6 \text{H}_2 (\text{NO}_2)_2 (\text{NH}_2) \text{OH}$                                  | 199.10          | $\text{C}_6 \text{H}_5 \text{O}_5 \text{N}_3$    |
| 34 Picric acid, see               | Trinitro phenol  |                 |  |

| Density<br>H <sub>2</sub> O=1. | Solubility in                     |  |                    | M.P.<br>°C. | B.P.<br>°C.   |          |
|--------------------------------|-----------------------------------|--|--------------------|-------------|---------------|----------|
|                                | Water.                            | Alcoh.                                 | Ether.             |             |               |          |
| 0.8850/20°                     |                                   |  |                    | 28          | 197—200       | 1        |
| 1.392/18.5°                    | d.                                | d.                                     |                    |             | 8             | 2        |
| 1.375/20°                      |                                   |  |                    | liq.        | 225           | 3        |
| 1.475                          | 23.5 : 100<br>/15°                | s.                                     | s.                 | 158         | d.            | 4        |
|                                | i.                                | i., s.h. C <sub>6</sub> H <sub>6</sub> | i.                 | 149—150     |               | 5        |
|                                | i.                                | i.                                     | i.                 | 219—220 d.  |               | 6        |
|                                | i.                                | s.                                     |                    | 208         | subl.         | 7        |
|                                |                                   |  |                    | 125—126     |               | 8        |
| 1.585—1.593                    | 18 : 100/99°                      | 1 : 10 (abs)<br>15°                    | 0.684 :<br>100/15° | 196—199 d.  |               | 9        |
|                                | s.                                | s                                      |                    | liq.        | d.            | 10       |
| 1.1286/15°                     |                                   |  |                    |             | 295           | 11       |
|                                | 1 : 460, h.<br>c.v.s.s.           | s.<br>i.<br>s.                         | i.                 | 348.5       | subl<br>subl. | 12<br>13 |
|                                |                                   |  |                    | 52          |               | 14       |
|                                |                                   |  |                    | 89—90       |               | 15       |
|                                | 1 : 60, h.                        | v.s.                                   | s.                 | 116         |               | 16       |
| 1.527/4°                       | s.                                | s. OS <sub>2</sub>                     |                    | 131.5       | 284.5         | 17       |
|                                | h.s.                              | s.                                     |                    | 75          | 290           | 18       |
|                                | s. acetic.                        | s.                                     | s                  | 228—229     | subl.         | 19       |
|                                | s.                                | s.                                     | s.                 | 144.5       |               | 20       |
|                                | c.s.s.                            | s.                                     | s.                 | 160—161     |               | 21       |
|                                |                                   | s.s.                                   | s.s.               | 222         |               | 22       |
|                                | s. H <sub>2</sub> SO <sub>4</sub> | s.                                     |                    | 115         |               | 23       |
| 1.4089/20°                     |                                   |  |                    |             | 275.4/726     | 24       |
|                                |                                   |  |                    | 41          | 276           | 25       |
|                                |                                   |  |                    | 77—78       | 259           | 26       |
|                                |                                   |  |                    |             |               | 27       |
| 0.9526/10°                     |                                   |  |                    | liq.        | 129           | 28       |
| 0.9726/0°                      | m.                                |  |                    | liq.        | 144—147       | 29       |
| 0.9742/0°                      |                                   |  |                    | liq.        | 142.5—144.5   | 30       |
|                                | s.                                | s.                                     | i.                 | 134.5—136   |               | 31       |
| 1.762/14°                      | i.                                | i.                                     | s. acetic.         | 188         |               | 32       |
|                                |                                   |  |                    |             |               |          |
|                                | s.s.                              | s., s.s.o.                             | s.s.               | 168—169     |               | 33       |
|                                |                                   |  |                    |             |               | 34       |

| Name.                                      | Formula.   | Formula Weight. | Empirical Formula. |
|--|--|-----------------|--------------------|
| 1 Piceryl chloride, 1:3:5:2                | $C_6H_2(NO_2)_3Cl$   | 247.54          | $C_6H_2O_6N_3Cl$   |
| 2 —, 1:2:4:5                               | "  | 247.54          | "                  |
| 3 Pimaric acid, <i>d</i>                   | $C_{20}H_{30}O_2$  | 302.34          | $C_{20}H_{30}O_2$  |
| 4 —, <i>l</i>                              | "  | 302.34          | "                  |
| 5 —, <i>i</i>                              | "  | 302.34          | "                  |
| 6 Pimelic acid                             | $C_7H_{12}O_4$   | 160.13          | $C_7H_{12}O_4$     |
| 7 Pinacolone                               | $CH_3COO.C(CH_3)_3$  | 100.13          | $C_6H_{12}O$       |
| 8 Pinacone                                 | $(CH_3)_2(C.OH)_2(CH_3)_2$   | 118.14          | $C_6H_{14}O_2$     |
| 9 Pinene, act.                             | $C_{10}H_{16}$   | 136.18          | $C_{10}H_{16}$     |
| 10 — hydrochloride                         | $C_{10}H_{17}Cl$   | 172.65          | $C_{10}H_{17}Cl$   |
| 11 Pinol                                   | $C_{10}H_{16}O$  | 152.18          | $C_{10}H_{16}O$    |
| 12 Pipecoline, methyl piperidine, $\alpha$ | $C_5H_{10}N.CH_3$  | 99.14           | $C_6H_{13}N$       |
| 13 —, —, $\beta$                           | "  | 99.14           | "                  |
| 14 —, —, $\gamma$                          | "  | 99.14           | "                  |
| 15 Piperazine, see                         | Diethylene diamine   |                 |                    |
| 16 Piperidine                              | $CH_2 \begin{matrix} \diagup CH_2.CH_2 \\ \diagdown CH_2.CH_2 \end{matrix} NH$ | 85.12           | $C_5H_{11}N$       |
| 17 Piperinic acid                          | $C_{12}H_{10}O_4$  | 218.14          | $C_{12}H_{10}O_4$  |
| 18 Piperonal                               | $(CH_2O)_4C_6H_3.CHO$  | 150.09          | $C_8H_6O_3$        |
| 19 Piperonyl alcohol                       | $C_8H_8O_3$  | 152.10          | $C_8H_8O_3$        |
| 20 Piperonylic acid                        | $C_8H_6O_3$  | 166.09          | $C_8H_6O_3$        |
| 21 Piperylene                              | $CH_2:CH.CH_2.CH:CH_2$   | 68.09           | $C_8H_6$           |
| 22 Pivalic acid                            | $(CH_3)_3C.COOH$   | 102.11          | $C_5H_{10}O_2$     |
| 23 Populin, benzoyl salicin                | $C_{20}H_{22}O_8.2H_2O$  | 426.31          | $C_{20}H_{22}O_8$  |
| 24 Prehntic acid, 1:2:3:5                  | $C_6H_2(COOH)_4$   | 254.10          | $C_{10}H_6O_8$     |
| 25 Prehntole, 1:2:3:4                      | $C_6H_2(CH_3)_4$   | 134.16          | $C_{10}H_{14}$     |
| 26 Propane                                 | $C_3H_8$   | 44.08           | $C_3H_8$           |
| 27 Propiolic acid                          | $CH:C.COOH$  | 70.03           | $C_3H_2O_2$        |
| 28 — alcohol                               | $CH:C.CH_2OH$  | 56.05           | $C_3H_4O$          |
| 29 Propionamide                            | $C_2H_5.CO.NH_2$   | 73.08           | $C_3H_7ON$         |
| 30 Propionic acid                          | $C_2H_5.COOH$  | 74.06           | $C_3H_6O_2$        |
| 31 Propionate, amyl                        | $C_2H_5.COO.C_5H_{11}$   | 144.17          | $C_8H_{16}O_2$     |
| 32 —, ethyl                                | $C_2H_5.COO.C_2H_5$  | 102.11          | $C_5H_{10}O_2$     |
| 33 —, methyl                               | $C_2H_5.COOCH_3$   | 88.08           | $C_4H_8O_2$        |
| 34 Propionic anhydride                     | $(C_2H_5.CO)_2O$   | 130.11          | $C_6H_{10}O_3$     |



| Density<br>$H_2O=1$ . | Solubility in |           |        | M.P.<br>°C. | B.P.<br>°C.            |    |
|-----------------------|---------------|-----------|--------|-------------|------------------------|----|
|                       | Water.        | Alcohol.  | Ether. |             |                        |    |
|                       | c.i., h.d.    | h.s.      | s.s.   | 83          |                        | 1  |
|                       |               |           |        | 116         |                        | 2  |
|                       | i.            | s.        | s.     | 210—211     | 282/15—20              | 3  |
|                       |               |           |        | 140—150     |                        | 4  |
|                       |               |           |        | 144—146     |                        | 5  |
| 0.7999/16°            | 1: 24/20°     | s.        | s.     | 105         | 272/100mm.             | 6  |
|                       | v.s.s.        |           |        |             | 106                    | 7  |
|                       | h.s.          | s.        |        | 35—38       | 171—172                | 8  |
| 0.865/15°             | i.            | s.        |        | — 50        | 156.4—156.6<br>/757mm. | 9  |
|                       |               | i.        |        | 133.5       | 210                    | 10 |
| 0.942/20°             |               |           |        | liq.        | 183—184                | 11 |
| 0.8622/0°             |               |           |        |             | 116—117<br>/714mm.     | 12 |
| 0.8635/0°             | v.s.          |           |        | liq.        | 125—126                | 13 |
| 0.8674/0°             | s.            |           |        | liq.        | 126.5—128              | 14 |
|                       |               |           |        |             |                        | 15 |
| 0.8615/20°            | m.            | s.        |        | — 17        | 106/759mm.             | 16 |
|                       | i.            | 1: 50, h. | s.     | 216—217     |                        | 17 |
|                       | h.s.          | s.        | m.     | 37          | 263                    | 18 |
|                       | h.s.          | m.        | li.    | 51          |                        | 19 |
|                       | h.s.s.        | h.s.      | s.s.   | 227—229     |                        | 20 |
|                       |               |           |        | liq.        | 40—41                  | 21 |
| 0.905/50°             | s.            |           |        | 35.3—35.5   | 163.7—163.8            | 22 |
|                       | 1: 42/100°    | v.s.      |        | 180         |                        | 23 |
|                       | s.            |           |        | 237—250     |                        | 24 |
|                       |               |           |        | — 4         | 204                    | 25 |
| 0.613/—25°            |               | 6: 1 vol. |        | — 195       | — 38                   | 26 |
|                       | s.            | s.        | s.     | 6           | 140—145,<br>d. 154     | 27 |
| 0.9628/21°            | s.            |           |        | — 17        | 114—115                | 28 |
| 1.0335                |               | s.        | s.     | 80          | 213                    | 29 |
| 0.9871/19.9°          | m.            | s.        | s.     | — 19.3      | 140.5                  | 30 |
| 0.887/0°              |               |           |        | liq.        | 160.2                  | 31 |
| 0.8964/16°            |               | s.        |        | — 72.6      | 99.1                   | 32 |
| 0.917/18.5°           |               |           |        |             | 79.6                   | 33 |
| 1.0169/15°            | i.            |           |        | liq.        | 165.8                  | 34 |

| Name.                                  | Formula.   | Formula Empirical<br>Weight. Formula. |
|--|--|---------------------------------------|
| 1 Propionitrile                        | $C_2H_5.CN$  | 55.07 $C_3H_5N$                       |
| 2 Propionyl chloride                   | $C_2H_5.COCl$  | 92.52 $C_3H_5OCl$                     |
| 3 — formic acid                        | see Keto-butyric acid  |                                       |
| 4 Propyl alcohol, norm.                | $CH_3.CH_2.CH_2OH$   | 60.08 $C_3H_8O$                       |
| 5 —, <i>iso</i> .                      | $CH_3.CHOH.CH_3$   | 60.08 „                               |
| 6 — aldehyde                           | $CH_3.CH_2.CHO$  | 58.06 $C_3H_6O$                       |
| 7 — amine, norm.                       | $C_2H_5.CH_2.NH_2$   | 59.10 $C_3H_9N$                       |
| 8 —, <i>iso</i> .                      | $(CH_3)_2.CH.NH_2$   | 59.10 „                               |
| 9 — benzene, norm.                     | $C_6H_5.C_2H_5$  | 120.14 $C_8H_{12}$                    |
| 10 —, cumene                           | $C_6H_5.CH_2.(CH_3)_2$   | 120.14 „                              |
| 11 — carbylamine, <i>iso</i> .         | $(CH_3)_2.CH.NC$   | 69.09 $C_3H_7N$                       |
| 12 — chloride, norm.                   | $C_2H_5.Cl$  | 78.53 $C_2H_5Cl$                      |
| 13 —, <i>iso</i> .                     | $(CH_3)_2.CHCl$  | 78.53 „                               |
| 14 — cyanide, norm.                    | $C_2H_5.ON$  | 69.09 $C_2H_5N$                       |
| 15 —, <i>iso</i> .                     | $(CH_3)_2.CH.ON$   | 69.09 „                               |
| 16 — mercaptan                         | $C_2H_5.SH$  | 76.14 $C_2H_6S$                       |
| 17 — nitrolic acid                     | $CH_3.CH_2.C(NO_2)NOH$   | 118.08 $C_3H_5O_3N_2$                 |
| 18 — pyridine, $\alpha$                | $C_3H_7.C_5H_4N$   | 121.14 $C_8H_{11}N$                   |
| 19 —, $\alpha$ <i>iso</i> .            | „ „  | 121.14 „                              |
| 20 —, $\gamma$ <i>iso</i> .            | „ „  | 121.14 „                              |
| 21 — sulphide                          | $(C_2H_5)_2:S$   | 118.20 $C_4H_{10}S$                   |
| 22 — thiocyanate, <i>iso</i> .         | $C_2H_5.NCS$   | 101.15 $C_2H_5NS$                     |
| 23 Propylene                           | $CH_3.CH:CH_2$   | 42.06 $C_3H_6$                        |
| 24 — bromide                           | $CH_3.CHBr.CH_2Br$   | 210.90 $C_3H_6Br_2$                   |
| 25 — ether                             | $C_2H_5O$  | 58.06 $C_2H_6O$                       |
| 26 — glycol, tri-<br>methylene alcohol | $CH_2OH.CH_2.CH_2OH$   | 76.08 $C_3H_8O_2$                     |
| 27 —, propylene<br>alcohol             | $CH_3.CHOH.CH_2OH$   | 76.08 „                               |
| 28 Protocatechuic acid,                | see Dihydroxy benzoic acid   |                                       |
| 29 — aldehyde, 1 : 3 : 4               | $C_6H_3(OH)_2CHO$  | 138.08 $C_7H_6O_3$                    |
| 30 Pseudo cumene, 1 : 2 : 4            | $C_6H_3(CH_3)_3$   | 120.14 $C_9H_{12}$                    |
| 31 — cumidine, 1 : 2 : 4 : 5           | $(CH_3)_3C_6H_2.NH_2$  | 135.16 $C_9H_{13}N$                   |
| 32 Pulegone                            | $C_{10}H_{16}O$<br>$N = CH$<br> | 152.18 $C_{10}H_{16}O$                |
| 33 Purine                              |                                 | 120.10 $C_5H_4N_4$                    |
| 34 Purpurin, see                       | Trihydroxy anthraquinone   |                                       |

| Density<br>H <sub>2</sub> O=1. | Solubility in |             |               | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|---------------|-------------|---------------|-------------|-------------|----|
|                                | Water.        | Alcohol.    | Ether.        |             |             |    |
| 01/0°                          | s.            |             |               | - 103.5     | 98          | 1  |
| 546/20°                        |               |             |               |             | 80          | 2  |
|                                |               |             |               |             |             | 3  |
| 066/15°                        | s.            | s.          | s.            | liq.        | 97.2        | 4  |
| 887/20°                        | s.            | s.          | s.            | liq.        | 82.7        | 5  |
| 066/20°                        | 1 : 5/20°     |             |               |             | 49.5/740    | 6  |
| 168/20°                        | s.            |             |               | liq.        | 49          | 7  |
| 90/18°                         | m.            |             |               | liq.        | 32—32.5     | 8  |
| 81/0°                          | i.            | s.          | s.            |             | 157—158     | 9  |
| 798/0°                         | i.            | s.          | s.            | - 75.1      | 152.5—153.5 | 10 |
|                                |               |             |               | liq.        | 87          | 11 |
| 91/18°                         |               |             |               |             | 44/744mm.   | 12 |
| 588/20°                        |               |             |               |             | 37          | 13 |
| 95/12.5°                       |               |             |               | liq.        | 118.5       | 14 |
|                                |               |             |               | liq.        | 107—108     | 15 |
|                                | v.s.s.        |             |               |             | 67          | 16 |
|                                | v.s.          | s.          | v.s.          | 74—75       |             | 17 |
| H <sub>2</sub> O               |               |             |               | liq.        | 165—168     | 18 |
| 342/0°                         | s.s.          |             |               |             | 158—159     | 19 |
| 439/0°                         |               |             |               |             | 177—178     | 20 |
| 14/17°                         |               |             |               | liq.        | 141.5—142.5 | 21 |
|                                |               |             |               |             | 137—137.5   | 22 |
| 98                             |               | 12 : 1 vol. |               |             | - 37        | 23 |
| 1463/17°                       |               |             |               |             | 130         | 24 |
|                                | s.            | s.          | s.            | liq.        | 35          | 25 |
| 526/18°                        | m.            | m.          | 1 : 12.5 vol. | liq.        | 216         | 26 |
| 51/0°                          | m.            |             |               | liq.        | 188—189     | 27 |
|                                |               |             |               |             |             | 28 |
|                                | 1 : 20, c.    | v.s.        | v.s.          | 153—154     |             | 29 |
| 810/15°                        |               |             |               |             | 167—167.6   | 30 |
|                                |               |             |               | 64          | 234—235     | 31 |
| 332/20°                        |               |             |               | liq.        | 221.2       | 32 |
|                                |               |             |               |             |             |    |
|                                | v.s.          | s.          | s. toluene    | 211—212     |             | 33 |
|                                |               |             |               |             |             | 34 |

| Name.   | Formula.   | Formula Empirical<br>Weight. Formula.                 |
|---|--|---|
| 1 Purpuroxanthene,                                | see Dihydroxy anthraquinone  |   |
| 2 Pyrazine  | $\begin{array}{c} \text{CH} \begin{array}{c} \diagup \text{CH:N} \diagdown \\ \diagdown \text{N:OH} \diagup \end{array} \text{CH} \end{array}$ | 80.07 $\text{C}_4\text{H}_4\text{N}_2$                |
| 3 Pyrazole  | $\begin{array}{c} \text{CH:N} \\   \quad \diagup \\ \text{CH:CH} \quad \text{NH} \end{array}$  | 68.07 $\text{C}_3\text{H}_4\text{N}_2$                |
| 4 Pyrazoline                                      | $\text{CH}_2.\text{CH}_2.\text{CH:N.NH}$   | 70.08 $\text{C}_3\text{H}_6\text{N}_2$                |
| 5 Pyrazolone                                      | $\text{CO.CH}_2.\text{CH:N.NH}$  | 84.07 $\text{C}_3\text{H}_4\text{ON}_2$               |
| 6 Pyrene  | $\text{C}_{16}\text{H}_{10}$   | 202.16 $\text{C}_{16}\text{H}_{10}$                   |
| 7 Pyridazine                                      | $\text{CH} \begin{array}{c} \diagup \text{CH.CH} \diagdown \\ \diagdown \text{N:N} \diagup \end{array} \text{CH}$                              | 80.07 $\text{C}_4\text{H}_4\text{N}_2$                |
| 8 Pyridine  | $\text{C}_5\text{H}_5\text{N}$   | 79.08 $\text{C}_5\text{H}_5\text{N}$                  |
| 9 — carboxylic acid, $\alpha$                     | see Picolinic acid   |   |
| 10 — — —, $\beta$                                 | see Nicotinic acid   |   |
| 11 — — —, $\gamma$ iso-nicotinic acid             | $\text{C}_5\text{H}_4\text{N.COOH}$  | 123.08 $\text{C}_6\text{H}_5\text{O}_2\text{N}$       |
| 12 — dicarboxylic acid, 1:3:4, cinchomeronic acid | $\text{C}_5\text{H}_3\text{N}:(\text{COOH})_2$   | 167.09 $\text{C}_7\text{H}_5\text{O}_4\text{N}$       |
| 13 — — —, 1:2:5, iso-cinchomeronic acid           | " " $(\frac{1}{2} \text{ or } 1\frac{1}{2} \text{ H}_2\text{O})$   | 167.09 "  |
| 14 — — —, 1:2:6, dipicolinic acid                 | " " $(1\frac{1}{2} \text{ H}_2\text{O})$   | 167.09 "  |
| 15 — — —, 1:3:5, dinicotinic acid                 | " "  | 167.09 "  |
| 16 — — —, 1:2:4, lutidinic acid                   | " " $(\text{H}_2\text{O})$   | 167.09 "  |
| 17 — — —, 1:2:3, quinolic acid                    | " "  | 167.09 "  |
| 18 — penta carboxylic acid                        | $\text{C}_5\text{N}(\text{COOH})_5 (2-3\text{H}_2\text{O})$  | 299.10 $\text{C}_{10}\text{H}_5\text{O}_{10}\text{N}$ |
| 19 — tricarboxylic acid, 1:2:3:4                  | $\text{C}_5\text{H}_2\text{N}(\text{COOH})_3.1\frac{1}{2}\text{H}_2\text{O}$   | 238.12 $\text{C}_8\text{H}_5\text{O}_6\text{N}$       |
| 20 — — —, 1:2:4:5                                 | " " $.2\text{H}_2\text{O}$   | 247.12 "  |
| 21 — — —, 1:3:4:5                                 | " " $.3\text{H}_2\text{O}$   | 265.14 "  |
| 22 — — —, 1:2:4:6                                 | " " $.2\text{H}_2\text{O}$   | 247.12 "  |
| 23 — — —, 1:2:3:5                                 | " " $.2\text{H}_2\text{O}$   | 247.12 "  |
| 24 — — —, 1:2:3:6                                 | " " $.2\text{H}_2\text{O}$   | 247.12 "  |

| Density<br>H <sub>2</sub> O=1. | Water.               | Solubility in<br>Alcohol.          | Ether.     | M.P.<br>°C.           | B.P.<br>°C. |    |
|--------------------------------|----------------------|------------------------------------|------------|-----------------------|-------------|----|
|                                |                      |                                    |            |                       |             | 1  |
|                                | s.                   | s.                                 | s., s. ao. | 47                    | 118/768.4   | 2  |
|                                | o.s.                 | s.                                 | s.         | 69                    | 186—188     | 3  |
|                                | m.                   | m.                                 | s.s.       | liq.                  | 144         | 4  |
|                                | s.                   | v.s.                               | v.s.s.     | 165                   |             | 5  |
|                                | v.s. OS <sub>2</sub> | 1.37<br>: 100/16°                  | v.s.       | 147                   | >360        | 6  |
| 1.1070/20°                     | m.                   | s.                                 | s., s. ao. | - 8                   | 208         | 7  |
| 0.9893/15°                     | m.                   |                                    |            | - 42                  | 115.5       | 8  |
|                                |                      |                                    |            |                       |             | 9  |
|                                |                      |                                    |            |                       |             | 10 |
|                                | s.s.                 | s.s. C <sub>6</sub> H <sub>6</sub> | v.s.s.     | 299 under<br>pressure |             | 11 |
|                                | h.v.s.s.             | s.s.                               | i.         | 258—259               |             | 12 |
|                                | h.s.                 | i.                                 | i.         | 236                   |             | 13 |
|                                | h.s.                 | v.s.s.                             |            | 226                   |             | 14 |
|                                | v.s.s.               |                                    |            | 323                   |             | 15 |
|                                | h.v.s.               | h.v.s.                             | i.         | 237                   |             | 16 |
|                                | 1 : 183/65°          | s.s.                               | v.s.s.     | 190—195               |             | 17 |
|                                | v.s.                 |                                    | v.s.s.     | d. 220                |             | 18 |
|                                | 1 : 83.9<br>/15°     | s.s.                               | v.s.s.     | 249—250               |             | 19 |
|                                | h.s.                 | h.v.s.s.                           | i.         | 235                   |             | 20 |
|                                | h.s.                 |                                    |            | 261 d.                |             | 21 |
|                                | s.                   |                                    | s.s.       | 227 d.                |             | 22 |
|                                | s.s.                 | s.                                 |            | 323                   |             | 23 |
|                                | v.s.                 |                                    | i.         | > 100                 | d. 130      | 24 |

| Name.                                       | Formula.   | Formula Weight. | Empirical Formula.                                  |
|---|--|-----------------|---|
| 1 Pyrimidine                                | $\begin{array}{c} \text{CH} \begin{array}{c} \diagup \text{CH.CH} \diagdown \\ \diagdown \text{N:CH} \diagup \end{array} \text{N} \end{array}$     | 80.07           | $\text{C}_4\text{H}_4\text{N}_2$                    |
| 2 Pyrocatechol, see                         | Dihydroxy benzene  |                 |   |
| 3 Pyrogallol, 1:2:3                         | $\text{C}_6\text{H}_3(\text{OH})_3$  | 126.08          | $\text{C}_6\text{H}_6\text{O}_3$                    |
| 4 — carboxylic acid,<br>1:2:3:4             | $\text{C}_6\text{H}_2(\text{OH})_3\text{COOH} \cdot \frac{1}{3}\text{H}_2\text{O}$   | 176.09          | $\text{C}_7\text{H}_6\text{O}_5$                    |
| 5 —dimethyl ether, 2:1:3                    | $\text{C}_6\text{H}_3(\text{OH})(\text{OCH}_3)_2$  | 154.12          | $\text{C}_8\text{H}_{10}\text{O}_3$                 |
| 6 — triethyl ether,<br>1:2:3                | $\text{C}_6\text{H}_3(\text{OC}_2\text{H}_5)_3$  | 210.2           | $\text{C}_{12}\text{H}_{18}\text{O}_3$              |
| 7 Pyro mellitic acid,<br>1:2:4:5            | $\text{C}_6\text{H}_2(\text{COOH})_4 \cdot \text{H}_2\text{O}$   | 272.12          | $\text{C}_{10}\text{H}_6\text{O}_8$                 |
| 8 — mucic acid                              | $\text{C}_4\text{H}_3\text{O}_4\text{COOH}$  | 112.16          | $\text{C}_5\text{H}_4\text{O}_5$                    |
| 9 — — —, <i>iso</i> .                       | „ „ „ $\cdot 2\text{H}_2\text{O}$  | 148.09          | „   |
| 10 — racemic acid                           | $\text{CH}_3\text{CO.COCOOH}$  | 88.05           | $\text{C}_5\text{H}_4\text{O}_3$                    |
| 11 — tartaric acid, methyl<br>succinic acid | $\text{CH}_3\text{CH}(\text{COOH})\text{CH}_2\text{COOH}$  | 132.09          | $\text{C}_5\text{H}_8\text{O}_4$                    |
| 12 — terebic acid                           | $\text{C}_5\text{H}_9\text{COOH}$  | 114.11          | $\text{C}_6\text{H}_{10}\text{O}_2$                 |
| 13 — tritartaric acid                       | $\text{C}_4\text{H}(\text{CH}_3)_2\text{O.COCOOH}$   | 140.10          | $\text{C}_7\text{H}_8\text{O}_3$                    |
| 14 Pyrone, $\gamma$                         | $\begin{array}{c} \text{CO} \begin{array}{c} \diagup \text{CH:CH} \diagdown \\ \diagdown \text{CH:CH} \diagup \end{array} \text{O} \end{array}$    | 96.06           | $\text{C}_5\text{H}_4\text{O}_2$                    |
| 15 — $\alpha$ -carboxylic acid              | $\text{C}_5\text{H}_3\text{O}_2\text{COOH}$  | 140.06          | $\text{C}_6\text{H}_4\text{O}_4$                    |
| 16 Pyroxylin                                | $\text{C}_{10}\text{H}_7(\text{ONO}_2)_6\text{O}_4$  | 594.23          | $\text{C}_{12}\text{H}_{14}\text{O}_{22}\text{N}_6$ |
| 17 Pyrrole                                  | $\begin{array}{c} \text{CH:CH} \diagup \text{NH} \\   \\ \text{CH:CH} \end{array}$   | 67.07           | $\text{C}_4\text{H}_5\text{N}$                      |
| 18 — $\alpha$ -carboxylic acid              | $\text{C}_4\text{H}_4\text{N.COCH}_3$  | 118.06          | $\text{C}_5\text{H}_5\text{O}_2\text{N}$            |
| 19 Pyrrolidine                              | $(\text{CH}_2)_4\text{:NH}$  | 71.10           | $\text{C}_4\text{H}_9\text{N}$                      |
| 20 Pyrroline                                | $\begin{array}{c} \text{CH:CH}_2 \diagup \text{NH} \\    \\ \text{CH:CH}_2 \end{array}$  | 69.09           | $\text{C}_4\text{H}_7\text{N}$                      |
| 21 Queroetin                                | $\begin{array}{c} (\text{OH})_2 \diagup \text{O.C.C}_6\text{H}_3(\text{OH})_2 \\    \\ \text{C}_6\text{H}_2 \diagdown \text{OC.C(OH)} \end{array}$ | 302.16          | $\text{C}_{15}\text{H}_{10}\text{O}_7$              |
| 22 Quercite                                 | $\text{C}_6\text{H}_{12}\text{O}_5$  | 164.13          | $\text{C}_6\text{H}_{12}\text{O}_5$                 |
| 23 Quercitrin                               | $\text{C}_{21}\text{H}_{22}\text{O}_{12} \cdot 2\text{H}_2\text{O}$  | 502.31          | $\text{C}_{21}\text{H}_{22}\text{O}_{12}$           |
| 24 Quinaldine                               | $\text{C}_9\text{H}_6\text{N.CH}_3$  | 143.13          | $\text{C}_{10}\text{H}_9\text{N}$                   |
| 25 Quinazine, see                           | Quinoxaline  |                 |   |

| Density<br>$H_2O=1$ . | Solubility in      |              |        | M.P.<br>°C. | B.P.<br>°C.          |    |
|-----------------------|--------------------|--------------|--------|-------------|----------------------|----|
|                       | Water.             | Alcohol.     | Ether. |             |                      |    |
|                       | s.                 | s.           |        | 20—22       | 123.5—124<br>/762mm. | 1  |
|                       |                    |              |        |             |                      | 2  |
| 1.463/40°             | 44 : 100<br>/13°   | s.           | s.     | 132         | 292—294<br>/730mm.   | 3  |
|                       | v.s.               | s.           | s.     | 195—200     | subl.                | 4  |
|                       | s.                 |              |        | 52          | 252                  | 5  |
|                       |                    |              |        | 39          |                      | 6  |
|                       | 14.2 : 100<br>/16° | v.s.         |        | 275         |                      | 7  |
|                       | 1 : 28/15°         | s.           | s.     | 131—132     | subl.                | 8  |
|                       | s.                 | v.s.         | s.     | 87          | 102/15mm             | 9  |
| 1.288/18°             | m.                 | m.           | m.     | 13.6        | 165                  | 10 |
| 1.410                 | 1 : 1.5/20°        | v.s.         | v.s.   | 112         | d.                   | 11 |
| 1.006/26°             | s.                 | s.           | s.     | 46          | 207                  | 12 |
|                       |                    |              |        |             |                      | 13 |
|                       | v.s.               |              |        | 32.5        | 210—215              | 14 |
|                       | s.s.               |              |        | d.250       |                      | 15 |
|                       | s.s. acetone       | i.           | i.     | expl.       |                      | 16 |
| 0.9481/20°            | i.                 | v.s.         | v.s.   | liq.        | 126.2                | 17 |
|                       | s.                 | s.           | s.     | d. 191.5    |                      | 18 |
| 0.879/0°              | m.                 |              |        | liq.        | 87.5—88.5            | 19 |
| 0.852/22.5°           |                    |              |        |             |                      |    |
| 0.9027/20°            | v.s.               |              |        | liq.        | 90—91                | 20 |
|                       |                    |              |        |             |                      |    |
| 1.5845/13°            | h.s.s.             | 1 : 18.2, h. | v.s.s. | 310—312     |                      | 21 |
|                       | s.                 | h.s.         | i.     | 225         | d.                   | 22 |
|                       | h.s.s.             | h.s.         | s.s.   |             |                      | 23 |
| 1.0646/20°            |                    | s.           |        |             | 246—247              | 24 |
|                       |                    |              |        |             |                      | 25 |

| Name.                         | Formula.   | Formula Empirical<br>Weight. Formula.              |
|-------------------------------|--|--|
| 1 Quinazalone                 | $\begin{array}{c} \text{CH} : \text{N} \\ \diagup \quad \diagdown \\ \text{C}_6\text{H}_4 \\ \diagdown \quad \diagup \\ \text{N} : \text{CH} \end{array}$  | 130.11 $\text{C}_8\text{H}_6\text{N}_2$            |
| 2 Quinhydrone                 | $\text{C}_{12}\text{H}_{10}\text{O}_4$   | 218.14 $\text{C}_{12}\text{H}_{10}\text{O}_4$      |
| 3 Quinic acid                 | $\text{C}_6\text{H}_7(\text{OH})_4\text{COOH}$   | 192.13 $\text{C}_7\text{H}_{12}\text{O}_6$         |
| 4 Quininic acid               | $\text{C}_{11}\text{H}_9\text{O}_3\text{N}$  | 203.14 $\text{C}_{11}\text{H}_9\text{O}_3\text{N}$ |
| 5 Quinitol, cis. 1 : 2        | $\text{C}_6\text{H}_4 : (\text{OH})_2 (\text{H}_6)$  | 116.13 $\text{C}_6\text{H}_{12}\text{O}_2$         |
| 6 —, trans. 1 : 2             | , ,  | 116.13 ,   |
| 7 —, cis. 1 : 3               | , ,  | 116.13 ,   |
| 8 —, cis. 1 : 4               | , ,  | 116.13 ,   |
| 9 —, trans. 1 : 4             | , ,  | 116.13 ,   |
| 10 —, isom. 1 : 4             | , ,  | 116.13 ,   |
| 11 Quinizarin, see            | Dihydroxy anthraquinone  |  |
| 12 Quinoline                  | $\begin{array}{c} \text{CH} : \text{CH} \\ \diagup \quad \diagdown \\ \text{C}_8\text{H}_4 \\ \diagdown \quad \diagup \\ \text{N} : \text{CH} \end{array}$ | 129.11 $\text{C}_9\text{H}_7\text{N}$              |
| 13 —, iso.                    | $\text{C}_9\text{H}_7\text{N}$   | 129.11 ,   |
| 14 Quinolinic acid, 1 : 2 : 3 | $\text{C}_8\text{H}_5\text{N}(\text{COOH})_2$  | 167.09 $\text{C}_7\text{H}_5\text{O}_4\text{N}$    |
| 15 Quinone, 1 : 4             | $\text{C}_6\text{H}_4\text{O}_2$   | 108.06 $\text{C}_6\text{H}_4\text{O}_2$            |
| 16 — chlorimide               | $\text{O.C}_6\text{H}_4.\text{N.Cl}$   | 141.53 $\text{C}_6\text{H}_4\text{ONCl}$           |
| 17 — dichlorimide             | $\text{C}_6\text{H}_4(\text{N.Cl})_2$  | 175.00 $\text{C}_6\text{H}_4\text{N}_2\text{Cl}_2$ |
| 18 — di-imine                 | $\text{NH} : \text{C}_6\text{H}_4 : \text{NH}$   | 106.09 $\text{C}_6\text{H}_4\text{N}_2$            |
| 19 — dioxime                  | $\text{C}_6\text{H}_4(\text{N.OH})_2$  | 138.10 $\text{C}_6\text{H}_6\text{O}_2\text{N}_2$  |
| 20 Quinoxaline                | $\begin{array}{c} \text{N} : \text{CH} \\ \diagup \quad \diagdown \\ \text{C}_6\text{H}_4 \\ \diagdown \quad \diagup \\ \text{N} : \text{CH} \end{array}$  | 130.11 $\text{C}_8\text{H}_6\text{N}_2$            |
| 21 Raffinose                  | $\text{C}_{18}\text{H}_{32}\text{O}_{16}$  | 594.43 $\text{C}_{18}\text{H}_{32}\text{O}_{16}$   |
| 22 Resorcinol, see            | Dihydroxy benzene  |  |
| 23 — methyl ether             | $\text{OH.C}_6\text{H}_4.\text{OCH}_3$   | 124.10 $\text{C}_7\text{H}_8\text{O}_2$            |
| 24 Resorcylic acid, 3 : 5 : 1 | $\text{C}_6\text{H}_3(\text{OH})_2\text{COOH} (1\frac{1}{2}\text{H}_2\text{O})$  | 154.08 $\text{C}_7\text{H}_6\text{O}_4$            |
| 25 —, 2 : 4 : 1               | , , $(3\text{H}_2\text{O})$  | 154.08 ,   |
| 26 Retene                     | $\text{C}_{18}\text{H}_{18}$   | 234.23 $\text{C}_{18}\text{H}_{18}$                |
| 27 Rhamnite                   | $\text{CH}_3(\text{CHOH})_4\text{CH}_2\text{OH}$   | 166.14 $\text{C}_6\text{H}_{14}\text{O}_5$         |
| 28 Rhamnose                   | $\text{CH}_3(\text{CHOH})_4\text{CHO.H}_2\text{O}$   | 182.15 $\text{C}_6\text{H}_{12}\text{O}_5$         |
| 29 Rhodizonic acid            | $\text{C}_6(\text{OH})_2\text{O}_4$  | 170.05 $\text{C}_6\text{H}_2\text{O}_6$            |
| 30 Ricinoleic acid            | $\text{C}_{18}\text{H}_{34}\text{O}_3$   | 298.36 $\text{C}_{18}\text{H}_{34}\text{O}_3$      |
| 31 Roccellic acid             | $\text{C}_{15}\text{H}_{30}(\text{COOH})_2$  | 300.34 $\text{C}_{17}\text{H}_{32}\text{O}_4$      |
| 32 Rosaniline                 | $\text{C}_{20}\text{H}_{21}\text{N}_3\text{O}$   | 319.24 $\text{C}_{20}\text{H}_{21}\text{ON}_3$     |



| Density<br>$H_2O=1.$ | Solubility in   |              |               | M.P.<br>°C. | B.P.<br>°C. |    |
|----------------------|-----------------|--------------|---------------|-------------|-------------|----|
|                      | Water.          | Alcohol.     | Ether.        |             |             |    |
|                      |                 |              |               | 48—48.5     | 243/772mm.  | 1  |
|                      | h.s.            | s.           | s.            | 171         | subl.       | 2  |
|                      | 1 : 2.5/9°      | v.s.s.       | v.s.s.        | 162         | d.          | 3  |
|                      | s.s.            | s.s.         | v.s.s.        | d. 280      |             | 4  |
|                      | s.              | s.           | v.s.s.        | 75—76       | 225         | 5  |
|                      |                 |              |               | 99—100      | 225         | 6  |
|                      |                 |              |               | 65          |             | 7  |
|                      |                 |              |               | 102         |             | 8  |
|                      |                 |              |               | 140         |             | 9  |
|                      |                 |              |               |             | 218—225     | 10 |
|                      |                 |              |               |             |             | 11 |
| 0944/20°             |                 | s.           | s. $CS_2$     | — 19.5      | 238         | 12 |
| 0986/20°             |                 | s.           | s.            | — 24.6      | 240/750mm   | 13 |
| 6.5 : 183            | s.s.            | v.s.s.       | 190—195       | d.          |             | 14 |
| 307-1.318            | h.s.            | s.           | s.            | 115.7       | subl.       | 15 |
|                      | h.s.            | s.           | h.s.          | 84.7—85     | d.          | 16 |
|                      | h.s.s.          | h.s.         | v.s.          | d. 124      |             | 17 |
|                      |                 |              |               | 124 d.      |             | 18 |
|                      | s. conc. $NH_3$ |              |               |             | d. 240      | 19 |
|                      | m.              | m.           | m.            | 27          | 225—226     | 20 |
|                      | 1 : 7/20°,      | v.s.s.       |               | an. 118—119 |             | 21 |
|                      | h.m.            |              |               |             |             | 22 |
|                      | s.s.            | s.s.         | s.s.          | liq.        | 243—244     | 23 |
|                      | h.v.s.          | s.           | s.            | 232—233     |             | 24 |
|                      | 1 : 381/17°     | s.           | s.            | 213         |             | 25 |
| 13/16°               |                 | 69 : 100/78° | v.s.          | 98          | 390         | 26 |
|                      | v.s.            | v.s.         | s.s. $OHCl_3$ | 121         |             | 27 |
| 4708/20°             | 60 : 100/20°    | s.           |               | 92—93, an.  |             | 28 |
|                      |                 |              |               | 122—126     |             |    |
|                      | s.              | i.           |               | d.          |             | 29 |
|                      |                 | m.           | m.            | 16—17       | 250/15mm.   | 30 |
|                      | l.              | s.           | s.            | 132         |             | 31 |
|                      | s.s.            | s.           | i.            |             |             | 32 |

| Name.                         | Formula.   | Formula Empirical                                     |
|-------------------------------|--|---|
|                               |  | Weight. Formula.                                      |
| 1 Rosinduline                 | $\text{HN} : \text{C}_{10}\text{H}_5 \begin{array}{c} \diagup \text{N} \\ \diagdown \text{N.C}_6\text{H}_5 \end{array} \text{C}_6\text{H}_5$ | 321.26 $\text{C}_{22}\text{H}_{15}\text{N}_3$         |
| 2 Rosolic acid                | $\text{C}_{20}\text{H}_{16}\text{O}_3$   | 304.23 $\text{C}_{20}\text{H}_{16}\text{O}_3$         |
| 3 Rubeanhydride               | $\text{NH}_2.\text{CS}.\text{CS}.\text{NH}_2$  | 120.18 $\text{C}_2\text{H}_4\text{N}_2\text{S}_2$     |
| 4 Ruberythric acid            | $\text{C}_{26}\text{H}_{28}\text{O}_{14}$  | 564.35 $\text{C}_{26}\text{H}_{28}\text{O}_{14}$      |
| 5 Rufigallic acid             | $\text{C}_{14}\text{H}_8\text{O}_8.2\text{H}_2\text{O}$  | 340.16 $\text{C}_{14}\text{H}_8\text{O}_8$            |
| 6 Rufopin                     | $\text{C}_{14}\text{H}_8\text{O}_8$  | 273.13 $\text{C}_{14}\text{H}_8\text{O}_8$            |
| 7 Rufol, see                  | Dihydroxy anthracene   |   |
| 8 Saccharic acid              | $\text{C}_4\text{H}_4(\text{OH})_4(\text{COOH})_2$   | 210.11 $\text{C}_6\text{H}_{10}\text{O}_8$            |
| 9 Saccharin                   | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{CO} \\ \diagdown \text{SO}_2 \end{array} \text{NH}$                                     | 183.15 $\text{C}_7\text{H}_5\text{O}_3\text{NS}$      |
| 10 Safrol                     | $\text{CH}_3 : \text{O}_2 : \text{C}_6\text{H}_3.\text{CH}_2.\text{CH} : \text{CH}_2$  | 162.13 $\text{C}_{10}\text{H}_{10}\text{O}_2$         |
| 11 —, iso.                    | $\text{CH}_3 : \text{O}_2 : \text{C}_6\text{H}_3.\text{CH} : \text{CH}.\text{CH}_3$  | 162.13 „  |
| 12 Salicin                    | $\text{C}_{13}\text{H}_{18}\text{O}_7$   | 286.21 $\text{C}_{13}\text{H}_{18}\text{O}_7$         |
| 13 Salicyl aldehyde, see      | Hydroxy benzaldehyde   |   |
| 14 — amide                    | $\text{C}_6\text{H}_4\text{OH}.\text{CONH}_2$  | 137.10 $\text{C}_7\text{H}_7\text{O}_2\text{N}$       |
| 15 — anilide                  | $\text{C}_6\text{H}_4\text{OH}.\text{CONH}.\text{C}_6\text{H}_5$   | 213.16 $\text{C}_{13}\text{H}_{11}\text{O}_2\text{N}$ |
| 16 Salicylic acid, see        | Hydroxy benzoic acid, o  |   |
| 17 Salicylate, ethyl          | $\text{C}_6\text{H}_4\text{OH}.\text{COO}.\text{C}_2\text{H}_5$  | 166.13 $\text{C}_9\text{H}_{10}\text{O}_3$            |
| 18 —, methyl                  | $\text{C}_6\text{H}_4\text{OH}.\text{COO}.\text{CH}_3$   | 152.10 $\text{C}_8\text{H}_8\text{O}_3$               |
| 19 —, phenyl                  | $\text{C}_6\text{H}_4\text{OH}.\text{COO}.\text{C}_6\text{H}_5$  | 214.15 $\text{C}_{13}\text{H}_{10}\text{O}_3$         |
| 20 Salicylic anhydride        | $(\text{C}_6\text{H}_4)_2\text{O}(\text{CO})_2$  | 240.13 $\text{C}_{14}\text{H}_8\text{O}_4$            |
| 21 Saligenin                  | $\text{C}_6\text{H}_4\text{OH}.\text{CH}_2.\text{OH}$  | 124.10 $\text{C}_7\text{H}_8\text{O}_2$               |
| 22 Santalic acid              | $\text{C}_{15}\text{H}_{14}\text{O}_5$   | 274.19 $\text{C}_{15}\text{H}_{14}\text{O}_5$         |
| 23 Santonin                   | $\text{C}_{15}\text{H}_{18}\text{O}_3$   | 246.22 $\text{C}_{15}\text{H}_{18}\text{O}_3$         |
| 24 Sarcosine                  | $\text{NH}_2.\text{CH}_3.\text{CH}_2.\text{COOH}$  | 89.08 $\text{C}_3\text{H}_7\text{O}_2\text{N}$        |
| 25 Sebacic acid               | $\text{COOH}.\text{(CH}_2)_8.\text{COOH}$  | 202.19 $\text{C}_{20}\text{H}_{38}\text{O}_4$         |
| 26 Selenium di-ethyl          | $(\text{C}_2\text{H}_5)_2\text{Se}$  | 137.3 $\text{C}_4\text{H}_{10}\text{Se}$              |
| 27 — di-methyl                | $(\text{CH}_3)_2\text{Se}$   | 109.3 $\text{C}_2\text{H}_6\text{Se}$                 |
| 28 Semicarbazide              | $\text{NH}_2.\text{CO}.\text{NH}.\text{NH}_2$  | 75.08 $\text{CH}_5\text{ON}_3$                        |
| 29 Serin                      | $\text{C}_2\text{H}_3(\text{OH})(\text{NH}_2).\text{COOH}$   | 105.08 $\text{C}_3\text{H}_7\text{O}_3\text{N}$       |
| 30 Silico-acetic acid         | $\text{CH}_3.\text{SiOOH}$   | 76.1 $\text{CH}_3\text{O}_2\text{Si}$                 |
| 31 — benzoic acid             | $\text{C}_6\text{H}_5.\text{SiOOH}$  | 138.1 $\text{C}_6\text{H}_5\text{O}_2\text{Si}$       |
| 32 — heptane                  | $(\text{C}_2\text{H}_5)_3\text{SiH}$   | 116.3 $\text{C}_6\text{H}_{16}\text{Si}$              |
| 33 Silicon phenyl trichloride | $\text{C}_6\text{H}_5.\text{SiCl}_3$   | 211.6 $\text{C}_6\text{H}_5\text{Cl}_3\text{Si}$      |
| 34 — — tri-ethyl              | $\text{C}_2\text{H}_5.\text{Si}(\text{C}_2\text{H}_5)_3$   | 192.3 $\text{C}_{12}\text{H}_{20}\text{Si}$           |
| 35 — tetra-ethyl              | $(\text{C}_2\text{H}_5)_4\text{Si}$  | 144.0 $\text{C}_8\text{H}_{20}\text{Si}$              |
| 36 — — methyl                 | $(\text{CH}_3)_4\text{Si}$   | 88.3 $\text{C}_4\text{H}_{12}\text{Si}$               |

| Density<br>$H_2O=1.$ | Solubility in       |             |                  | M.P.<br>°C. | B.P.<br>°C. |    |
|----------------------|---------------------|-------------|------------------|-------------|-------------|----|
|                      | Water.              | Alcohol.    | Ether.           |             |             |    |
|                      | i.                  | s.          | s.               | 198—199     |             | 1  |
|                      | v.s.s.              | h.v.s.      | s.               | d.          |             | 2  |
|                      | v.s.s.              | v.s.        | v.s.             |             |             | 3  |
|                      | h.s.                | s.s.        | s.s.             | 258—260     |             | 4  |
|                      | h.s.s.              | s.s.        | s.s.             | subl.       |             | 5  |
|                      | h.s.s.              | s.          | s.s.             | subl.       | d           | 6  |
|                      |                     |             |                  |             |             | 7  |
|                      | v.s.                | s.          | s.s.             |             |             | 8  |
|                      | 0.43 :<br>100/25°   | v.s.        | v.s. xylene      | 220 d       |             | 9  |
| .114/0°              | i.                  | s.          |                  | 8           | 233         | 10 |
| (liq.)               | i.                  | s.          |                  |             | 251         | 11 |
| .426—                | 1 : 28/15°          | s.          | i.               | 201         | d.          | 12 |
| 1.434/26°            |                     |             |                  |             |             | 13 |
|                      | s.s.                |             | m.               | 142         | subl.       | 14 |
|                      | h.s.s.              | s.          | 1 : 2/15°        | 134—135     |             | 15 |
|                      |                     |             |                  |             |             | 16 |
| .1843/20°            |                     |             |                  | 1.3         | 231.5       | 17 |
| .182/16°             | s.s.                | s.          |                  | — 8.3       | 224         | 18 |
|                      |                     | h.v.s.      | s.               | 42          | 173/12mm    | 19 |
|                      | i.                  | s.          | s.               | 200—201     | d.          | 20 |
| .1613/25°            | 1 : 15/22°,<br>h.m. | v.s.        | v.s.             | 86          | subl.       | 21 |
|                      | s.                  | s.          | v.s. s. $C_6H_6$ | 104         |             | 22 |
| .1866                | v.s.s.              | s.          | s., s. $CHCl_3$  | 169—170     | subl. d.    | 23 |
|                      | s.s.                | s.s.        |                  | 210—215     |             | 24 |
|                      | h.s.s.              | s.          | s.               | 133—133.5   | 294.5/100   | 25 |
| > $H_2O$<br>> $H_2O$ | 1 : 50/100°         |             | v.s.             | liq.        | 108         | 26 |
|                      |                     |             |                  | liq.        | 58.2        | 27 |
|                      | s.                  | s. $C_6H_6$ | s. $CHCl_3$      | 96          |             | 28 |
|                      | 1 : 24/20°          | i.          | i.               | 146 d.      |             | 29 |
|                      | i.                  |             |                  |             |             | 30 |
|                      |                     |             | s.               | 92          |             | 31 |
| .751/0°              |                     |             | s.               | liq.        | 107         | 32 |
|                      | d.                  | d.          |                  | liq.        | 197         | 33 |
| .9043/0°             | i.                  |             | s.               | liq.        | 230         | 34 |
| .8341/0°             | i.                  |             | s.               |             | 153         | 35 |
| < $H_2O$             |                     |             |                  | liq.        | 26—27       | 36 |

| Name.                    | Formula.                           | Formula Weight. | Empirical Formula. |
|--------------------------|------------------------------------|-----------------|--------------------|
| 1 Skatole, see           | Methyl indol.                      |                 |                    |
| 2 Sorbic acid            | $C_6H_7.COOH$                      | 112.09          | $C_6H_8O_2$        |
| 3 Sorbite                | $C_6H_{14}O_6. \frac{1}{2}H_2O$    | 191.15          | $C_6H_{14}O_8$     |
| 4 Sorbose                | $C_6H_{12}O_6$                     | 180.13          | $C_6H_{12}O_6$     |
| 5 Stearic acid           | $C_{17}H_{35}.COOH$                | 284.38          | $C_{18}H_{36}O_2$  |
| 6 Stearin                | $C_{17}H_{35}(C_{18}H_{35}O_2)_3$  | 891.17          | $C_{57}H_{119}O_6$ |
| 7 Stearolic acid         | $C_{17}H_{31}.COOH$                | 280.35          | $C_{18}H_{32}O_2$  |
| 8 Stearone               | $C_{35}H_{70}O$                    | 506.74          | $C_{35}H_{70}O$    |
| 9 Stearoxylie acid       | $C_{18}H_{32}O_4$                  | 312.35          | $C_{18}H_{32}O_4$  |
| 10 Stilbene              | $C_6H_5.CH:CH.C_6H_5$              | 180.17          | $C_{14}H_{12}$     |
| 11 Styracine             | $C_8H_7.COO.C_6H_9$                | 264.22          | $C_{14}H_{16}O_2$  |
| 12 Styroline             | $C_6H_5.CH:CH_2$                   | 104.10          | $C_8H_8$           |
| 13 Suberane, see         | Cyclo-heptane                      |                 |                    |
| 14 Suberic acid          | $C_6H_{12}(COOH)_2$                | 174.15          | $C_8H_{14}O_4$     |
| 15 Suberone, see         | Cyclo-heptanone                    |                 |                    |
| 16 Succinamide           | $C_2H_4:(CONH_2)_2$                | 116.10          | $C_4H_8O_2N_2$     |
| 17 Succinic acid         | $C_2H_4:(COOH)_2$                  | 118.07          | $C_4H_6O_4$        |
| 18 —, <i>iso</i> .       | $CH_3.CH:(COOH)_2$                 | 118.07          | "                  |
| 19 Succinate, calcium    | $C_2H_4O_2Ca$                      | 156.12          | $C_2H_4O_2Ca$      |
| 20 —, ferrous, basic     | $(C_2H_4O_2)FeOH$                  | 188.90          | $C_4H_5O_4Fe$      |
| 21 —, ethyl              | $C_2H_4:(COOC_2H_5)_2$             | 174.15          | $C_4H_{14}O_4$     |
| 22 —, methyl             | $C_2H_4:(COOCH_3)_2$               | 146.11          | $C_4H_{10}O_4$     |
| 23 Succinic anhydride    | $C_2H_4:(CO)_2O$                   | 100.05          | $C_4H_4O_3$        |
| 24 — aldehyde, $\alpha$  | $C_2H_4:(CHO)_2$                   | 86.07           | $C_4H_6O_2$        |
| 25 —, $\beta$            | " "                                | 86.07           | "                  |
| 26 —, $\gamma$           | " "                                | 86.07           | "                  |
| 27 —, $\delta$           | " "                                | 86.07           | "                  |
| 28 —, $\epsilon$         | " "                                | 86.07           | "                  |
| 29 — nitrile             | $C_2H_4:(CN)_2$                    | 80.07           | $C_4H_4N_2$        |
| 30 Succinimide           | $C_2H_4:(CO)_2:NH.H_2O$            | 117.09          | $C_4H_5O_2N$       |
| 31 Succinyl chloride     | $C_2H_4:(COCl)_2$                  | 154.97          | $C_4H_4O_2Cl_2$    |
| 32 Sucrose, see          | Cane sugar                         |                 |                    |
| 33 Sulphanilic acid, see | Amino benzene sulphonic acid       |                 |                    |
| 34 Sulpho acetic acid    | $CH_2(SO_3H)COOH.1\frac{1}{2}H_2O$ | 167.13          | $C_2H_4O_8S$       |
| 35 Sulphonal             | $(CH_3)_2C:(SO_2.C_2H_5)_2$        | 228.28          | $C_7H_{16}O_4S_2$  |
| 36 Sylvan, see           | Methyl furfuran                    |                 |                    |
| 37 Sylvestrine           | $C_{10}H_{16}$                     | 136.18          | $C_{10}H_{16}$     |
| 38 Tannic acid           | $C_{14}H_{10}O_9$                  | 322.15          | $C_{14}H_{10}O_9$  |

| Density<br>$H_2O=1$ . | Solubility in |          |                 | M.P.<br>°C. | B.P.<br>°C.  |    |
|-----------------------|---------------|----------|-----------------|-------------|--------------|----|
|                       | Water.        | Alcohol. | Ether.          |             |              |    |
|                       |               |          |                 | 134.5       | 228 d.       | 1  |
|                       | h.s.          | s.       | s.              | 110—111     |              | 2  |
|                       | s.            | h.s.     |                 | 154         |              | 3  |
| 0.654/15°             | v.s.          | h.s.s.   |                 | 69.3        | 291/100mm.   | 4  |
| 0.8521/69.5°          | i.            | h.s.     |                 | 71.2        |              | 5  |
| 0.9425/65.5°          | i.            | h.s.     | s.              | 48          | 260          | 6  |
|                       | i.            | h.s.     | s.              | 87.8        |              | 7  |
| 0.7979                | i.            | h.s.s.   | s.s.            | 86          |              | 8  |
|                       | i.            | h.s.     | s.s.            | 124—125     | 306—307      | 9  |
| 0.9707/119°           |               | h.s.     | s.              | 44          |              | 10 |
|                       | i.            | s.       | s., s. $CHCl_3$ | liq.        | 145—146      | 11 |
| 0.9074/20°            | i.            | m.       | s.              |             |              | 12 |
|                       |               |          |                 |             |              | 13 |
|                       | h.s.          | s.       | v.s.s.          | 140         | 300          | 14 |
|                       |               |          |                 |             |              | 15 |
|                       | h.s.          | i.       | i.              | 90          |              | 16 |
| 1.552                 | 120 : 100, h. | 7 : 100  | s.s.            | 184—185     | 235          | 17 |
| 1.455                 | 1 : 1.5/15°   | s.       | s.              | 130 d.      |              | 18 |
|                       | s.s.          |          | i.              |             |              | 19 |
|                       | s.s.          |          | i. acetic.      | d 180       |              | 20 |
| 1.0465/15°            | i.            |          |                 | — 20.8      | 216.5        | 21 |
| 1.1611/15°            |               |          |                 | 18.5        | 195.2        | 22 |
|                       | s.s.          | s.       | v.s.s.          | 119.6       | 261          | 23 |
|                       | s.            | s.       | s.              |             | 169—170      | 24 |
|                       |               |          |                 |             | 169/761mm    | 25 |
|                       |               |          |                 | 64          |              | 26 |
|                       |               |          |                 | 130—140     |              | 27 |
|                       |               |          |                 | 90—100 d.   |              | 28 |
| 0.9848/63.1°          |               |          |                 | 54.5        | 158—160/20mm | 29 |
|                       | s.            | s.       |                 | 125—126     | 287—288      | 30 |
| 1.4123/15°            |               |          |                 | 17          | 190          | 31 |
|                       |               |          |                 |             |              | 32 |
|                       |               |          |                 |             |              | 33 |
|                       | s.            |          |                 | 75          | subl.        | 34 |
|                       | h.s.          | 1 : 2, h | s.s.            | 125—126     | 300 d.       | 35 |
|                       |               |          |                 | liq.        |              | 36 |
| 0.851/16°             |               |          |                 | d           | 176—177      | 37 |
|                       | s.            | s.s.     | v.s.s.          |             |              | 38 |

| Name.                                   | Formula.   | Formula Weight. | Empirical Formula.                              |
|---|--|-----------------|---|
| 1 Tartaric acid, dextro                 | $\text{COOH} \cdot (\text{CHOH})_2 \cdot \text{COOH}$  | 150.07          | $\text{C}_4\text{H}_6\text{O}_6$                |
| 2 —, laevo                              | „ „  | 150.07          | „   |
| 3 —, racemic                            | „ „ $\cdot \text{H}_2\text{O}$   | 168.09          | „   |
| 4 —, meso.                              | „ „ $\cdot \text{H}_2\text{O}$   | 168.09          | „   |
| 5 Tartrate, potassium                   | $\text{C}_4\text{H}_4\text{O}_6\text{K}_2 \cdot (\frac{1}{2}\text{H}_2\text{O})$   | 226.25          | $\text{C}_4\text{H}_4\text{O}_6\text{K}$        |
| 6 —, — hydrogen                         | $\text{C}_4\text{H}_4\text{O}_6\text{K}$   | 188.16          | $\text{C}_4\text{H}_4\text{O}_6\text{K}$        |
| 7 —, — antimonyl                        | $\text{C}_4\text{H}_4\text{O}_6\text{K} \cdot \text{SbO} (\frac{1}{2}\text{H}_2\text{O})$  | 323.35          | $\text{C}_4\text{H}_4\text{O}_6\text{K Sb}$     |
| 8 —, — sodium, Rochelle salt            | $\text{C}_4\text{H}_4\text{O}_6\text{KNa} (4\text{H}_2\text{O})$   | 210.15          | $\text{C}_4\text{H}_4\text{O}_6\text{KNa}$      |
| 9 —, calcium                            | $\text{C}_4\text{H}_4\text{O}_6\text{Ca} (\text{H}_2\text{O})$   | 188.12          | $\text{C}_4\text{H}_4\text{O}_6\text{Ca}$       |
| 10 —, di-ethyl                          | $\text{C}_8\text{H}_{14}\text{O}_6 (\text{C}_2\text{H}_5)_2$   | 206.15          | $\text{C}_8\text{H}_{14}\text{O}_6$             |
| 11 —, ethyl                             | $\text{C}_8\text{H}_{14}\text{O}_6 \cdot \text{C}_2\text{H}_5$   | 178.11          | $\text{C}_8\text{H}_{14}\text{O}_6$             |
| 12 Tartronic acid                       | $\text{CHOH} : (\text{COOH})_2 \cdot \frac{1}{2}\text{H}_2\text{O}$  | 147.07          | $\text{C}_3\text{H}_4\text{O}_5$                |
| 13 Taurine                              | $\text{C}_2\text{H}_4\text{NH}_2 \cdot \text{SO}_3\text{H}$  | 125.14          | $\text{C}_2\text{H}_7\text{O}_3\text{NS}$       |
| 14 Taurocholic acid                     | $\text{C}_{26}\text{H}_{45}\text{NO}_7\text{S}$  | 515.56          | $\text{C}_{26}\text{H}_{45}\text{O}_7\text{NS}$ |
| 15 Tellurium di-ethyl                   | $(\text{C}_2\text{H}_5)_2\text{Te}$  | 185.6           | $\text{C}_4\text{H}_{10}\text{Te}$              |
| 16 — dimethyl                           | $(\text{CH}_3)_2\text{Te}$   | 157.6           | $\text{C}_2\text{H}_6\text{Te}$                 |
| 17 Teraconic acid                       | $(\text{CH}_3)_2\text{C} : \text{C} : \text{C} (\text{COOH}) \text{CH}_2 \cdot \text{COOH}$  | 158.12          | $\text{C}_7\text{H}_{10}\text{O}_4$             |
| 18 Terebene                             | $\text{C}_{10}\text{H}_{16}$   | 136.18          | $\text{C}_{10}\text{H}_{16}$                    |
| 19 Terebentylic acid                    | $\text{C}_8\text{H}_{10}\text{O}_2$  | 138.12          | $\text{C}_8\text{H}_{10}\text{O}_2$             |
| 20 Terebic acid                         | $\text{C}_7\text{H}_{10}\text{O}_4$  | 158.12          | $\text{C}_7\text{H}_{10}\text{O}_4$             |
| 21 Terpenylic acid                      | $\text{C}_8\text{H}_{12}\text{O}_4 \cdot \text{H}_2\text{O}$   | 190.16          | $\text{C}_8\text{H}_{12}\text{O}_4$             |
| 22 Terpinene, $\alpha$                  | $\text{C}_{10}\text{H}_{16}$   | 136.18          | $\text{C}_{10}\text{H}_{16}$                    |
| 23 —, $\beta$                           | $\text{C}_{10}\text{H}_{16}$   | 136.18          | $\text{C}_{10}\text{H}_{16}$                    |
| 24 Terpineol, $\alpha$                  | $\text{C}_{10}\text{H}_{17}\text{OH}$  | 154.19          | $\text{C}_{10}\text{H}_{18}\text{O}$            |
| 25 Terpin hydrate                       | $\text{C}_{10}\text{H}_{18} (\text{OH})_2 \cdot \text{H}_2\text{O}$  | 190.23          | $\text{C}_{10}\text{H}_{20}\text{O}_2$          |
| 26 Terpinolene                          | $\text{CH}_3 \cdot \text{C} \begin{array}{l} \diagup \text{CH} \cdot \text{CH}_2 \\ \diagdown \text{CH}_2 \cdot \text{CH}_2 \end{array} \text{C} : \text{C} \begin{array}{l} \diagup \text{CH}_3 \\ \diagdown \text{CH}_3 \end{array}$ | 136.18          | $\text{C}_{10}\text{H}_{16}$                    |
| 27 Tetra-brom-benzene,<br>1 : 2 : 3 : 5 | $\text{C}_6\text{H}_2\text{Br}_4$  | 393.73          | $\text{C}_6\text{H}_2\text{Br}_4$               |
| 28 — — —, 1 : 2 : 4 : 5                 | „  | 393.73          | „   |
| 29 — benzoquinone,<br>3 : 4 : 5 : 6     | $\text{C}_6\text{Br}_4\text{O}_2$  | 423.71          | $\text{C}_6\text{O}_2\text{Br}_4$               |
| 30 — — —, 2 : 3 : 5 : 6                 | „  | 423.71          | „   |
| 31 — chlor aniline,<br>2 : 3 : 4 : 5    | $\text{C}_6\text{HCl}_4 \cdot \text{NH}_2$   | 230.90          | $\text{C}_6\text{H}_3\text{Cl}_4\text{N}$       |
| 32 — — —, 2 : 3 : 5 : 6                 | „  | 230.90          | „   |

| Density<br>$H_2O=1.$ | Solubility in   |          |             | M.P.<br>°C.       | B.P.<br>°C. |    |
|----------------------|-----------------|----------|-------------|-------------------|-------------|----|
|                      | Water.          | Alcohol. | Ether.      |                   |             |    |
| .76                  | 139 : 100/20°   | 1 : 5    | i.          | 168—170           |             | 1  |
| .76                  | 139 : 100/20°   | s.       | i.          | 169—170           |             | 2  |
| .78 an.              | 20.6 : 100/20°  | s.s.     |             | 205               |             | 3  |
| .67                  | v.s.            |          |             | 140               |             | 4  |
| .975                 | s.              | s.s.     |             | an. 180           |             | 5  |
| .956                 | h.s.            | s.s.     |             |                   |             | 6  |
| .6                   | v.s.            | i.       |             |                   |             | 7  |
| .77                  | s.s.            |          | s. ac., alk |                   |             | 8  |
|                      | v.s.s.          | i.       |             | an. 100           | d. 200      | 9  |
| .2059/20°            | i.              | s.       | s.          | liq.              |             | 10 |
|                      |                 |          |             | 90                |             | 11 |
|                      |                 | s.       | s.          | subl. 110—<br>120 | d. 186      | 12 |
|                      | h.s.            | i.       | i.          | d. 240            |             | 13 |
|                      | s.              | s.       | s.s.        | 180               |             | 14 |
|                      |                 |          |             | liq.              | 137—138     | 15 |
|                      | i.              |          |             | liq.              | 82          | 16 |
|                      | s.              | s.       | s.          | 161—163 d.        |             | 17 |
| .876/0°              |                 |          |             | liq.              | 160         | 18 |
|                      | h.s.            | s.       | s.          | 90                | 250         | 19 |
|                      | h.s.            | s.       | s.          | 174               |             | 20 |
|                      | s.              | s.       | s.          | an. 90            | d.          | 21 |
|                      |                 |          |             |                   | 176/751mm.  | 22 |
|                      |                 |          |             |                   | 173—174     | 23 |
| .9357/20°            | i.              | s.       | s.          | 35                | 217.7       | 24 |
|                      | h.s.            | s.       |             | an. 105           | 258         | 25 |
|                      | h.s.            | s.       | s.          | 174               | d.          | 26 |
|                      |                 | h.v.s.   | s.          | 98.5              | 329         | 27 |
| .027/20°             |                 | s.       |             | 177—178           |             | 28 |
|                      | i., s. $C_6H_6$ | h.s.     | s.s.        | 150—151           |             | 29 |
|                      |                 | s.       | s.          | 118               | 300         | 30 |
|                      |                 |          |             | 90                |             | 31 |
|                      |                 |          |             |                   |             | 32 |

| Name.   | Formula.   | Formula Weight. | Empirical Formula. |
|---|--|-----------------|--------------------|
| 1 Tetra chlor benzene,<br>1 : 2 : 3 : 4       | $C_6H_2Cl_4$   | 215.89          | $C_6H_2Cl_4$       |
| 2 ———, 1 : 2 : 3 : 5                          | "  | 215.89          | "                  |
| 3 ———, 1 : 2 : 4 : 5                          | "  | 215.89          | "                  |
| 4 — ethane, $\alpha \alpha \alpha \beta$      | $CH_2Cl.CCl_3$   | 167.87          | $C_2H_2Cl_4$       |
| 5 ———, $\alpha \alpha \beta \beta$            | $CHCl_2.CHCl_2$  | 167.87          | "                  |
| 6 — ether                                     | $CCl_3.CHCl.O.C_2H_5$  | 211.91          | $C_4H_5OCl_4$      |
| 7 — hydroquinone                              | $C_6Cl_4(OH)_2$  | 247.89          | $C_6H_2O_2Cl_4$    |
| 8 — phthalic acid                             | $C_6Cl_4:(COOH)_2$   | 303.90          | $C_8H_2O_2Cl_4$    |
| 9 — anhydride                                 | $C_6Cl_4:(CO)_2O$  | 285.88          | $C_8O_2Cl_4$       |
| 10 Tetradecane                                | $C_{14}H_{30}$   | 198.31          | $C_{14}H_{30}$     |
| 11 Tetra decylene                             | $C_{14}H_{28}$   | 196.29          | $C_{14}H_{28}$     |
| 12 — ethyl ammonium<br>hydroxide              | $(C_2H_5)_4N.OH$   | 219.28          | $C_8H_{21}ON$      |
| 13 — benzene, 1 : 2 : 3 : 4                   | $C_6H_2(O_2H_5)_4$   | 190.25          | $C_{14}H_{22}$     |
| 14 ———, 1 : 2 : 4 : 5                         | "  | 190.25          | "                  |
| 15 — hydro benzene,<br>1 : 2 : 3 : 4          | $C_6H_6.H_4$   | 82.11           | $C_6H_{10}$        |
| 16 — benzoic acid                             | $CH_2 \begin{array}{l} \diagup CH_2.CH \\ \diagdown CH_2.CH_2 \end{array} \gg C.CO_2H$ | 126.12          | $C_7H_{10}O_2$     |
| 17 — naphthalene,<br>1 : 2 : 3 : 4            | $C_{10}H_8.H_4$  | 132.15          | $C_{10}H_{12}$     |
| 18 — naphthol, $\alpha$                       | $OH.C_6H_3 \begin{array}{l} \diagup CH_2.CH_2 \\ \diagdown CH_2.CH_2 \end{array}$      | 148.15          | $C_{10}H_{12}O$    |
| 19 — $\beta$ naphthylamine,<br>1 : 2 : 3 : 4  | $C_{10}H_{13}N$  | 147.16          | $C_{10}H_{13}N$    |
| 20 — $\alpha$ naphthylamine,<br>5 : 6 : 7 : 8 | "  | 147.16          | "                  |
| 21 — phenol,<br>2 : 1 : 2 : 3 : 4             | $C_6H_5.OH.H_4$  | 98.11           | $C_6H_{10}O$       |
| 22 — phthalic acid                            | $C_8H_6O_2.H_4$  | 170.12          | $C_8H_{10}O_2$     |
| 23 — quinoline, 1 : 2 : 3 : 4                 | $C_9H_7N.H_4$  | 133.14          | $C_9H_{11}N$       |
| 24 ———, <i>iso.</i> , 1 : 2 : 3 : 4           | "  | 133.14          | "                  |
| 25 — hydroxy anthraquinones                   |  |                 |                    |
| 26 Oxypurpurin                                | $C_{14}H_4O_2(OH)_4$   | 272.13          | $C_{14}H_8O_6$     |
| 27 Anthrachrysone                             | " " $.2H_2O$   | 308.16          | "                  |
| 28 Rufopin                                    | " "  | 272.13          | "                  |
| 29 $\alpha$ -Oxy anthra-<br>gallol            | " "  | 272.13          | "                  |



| Density<br>$H_2O=1.$ | Solubility in |          |           | M.P.<br>°C. | B.P.<br>°C.  |    |
|----------------------|---------------|----------|-----------|-------------|--------------|----|
|                      | Water.        | Alcohol. | Ether.    |             |              |    |
|                      |               | s.s.     | v.s.      | 45—46       | 254          | 1  |
|                      |               | h.s.     |           | 51          | 246          | 2  |
| 1.734/10°            | v.s. $C_6H_6$ | v.s.s    | s.        | 137—138     | 243—246      | 3  |
| 1.5825/0°            |               |          |           |             | 129—130      | 4  |
| 1.614/0°             |               |          |           |             | 147          | 5  |
| 1.438/0°             |               |          |           | liq.        | 189.7        | 6  |
|                      | i.            | v.s.     | v.s.      | 230         | subl.        | 7  |
|                      | i.            | c.v.s.s. | i.        | 250         |              | 8  |
|                      | i.            |          | v.s.      | 252         |              | 9  |
| 0.764/20°            |               |          |           | 5           | 252.5        | 10 |
| 0.774/15°            |               |          |           | — 12        | 127/15mm.    | 11 |
|                      | v.s.          | s.       |           | 49—50       |              | 12 |
|                      |               |          |           |             | 254          | 13 |
|                      |               |          |           |             | 250          | 14 |
|                      |               |          |           | liq.        | 80—81        | 15 |
| 1.109/20°            | s.s.          |          |           | 29          | 240—243      | 16 |
| 0.981/12.5°          |               |          |           | liq.        | 206          | 17 |
|                      | h.s.s         | v.s.     | v.s.      | 69          | 264/716mm.   | 18 |
|                      | v.s.          | s.       | s.        |             | 249.5/710mm. | 19 |
| 1.063/16°            | s.            | s.       | s.        |             | 275/712mm.   | 20 |
|                      | s.            |          |           | liq.        | 166          | 21 |
|                      | v.s.          |          |           | 120 in vac. |              | 22 |
| 1.0627/15°           | s.            |          |           |             | 251          | 23 |
|                      |               |          |           |             | 229—230      | 24 |
|                      |               |          |           |             |              | 25 |
|                      | v.s.s         | v.s.s.   | s. acetic | > 290       |              | 26 |
|                      | i.            | s.       | v.s.s     | > 360       |              | 27 |
|                      | h.s.s.        | s.       | s.s.      | subl.       | u.           | 28 |
|                      | v.s.s.        | s.       | s.s.      | > 360       |              | 29 |

| Name. |   | Formula.                                     | Formula Weight. | Empirical Formula.   |
|-------|---|--|-----------------|----------------------|
| 1     | $\beta$ -Oxy anthra-gallol                | $C_{14}H_4O_2(OH)_4$                         | 272.13          | $C_{14}H_8O_6$       |
| 2     | Quinalizarin                              | " "  | 272.13          | " "                  |
| 3     | Tetra hydroxy benzene, 1:2:4:5            | $C_6H_2(OH)_4$                               | 142.08          | $C_6H_6O_4$          |
| 4     | — benzoic acid                            | $C_6H(OH)COOH$                               | 186.08          | $C_7H_6O_6$          |
| 5     | — quinone, 2:3:5:6                        | $C_6O_2(OH)_4$                               | 172.06          | $C_6H_4O_6$          |
| 6     | — iodo pyrrole, 2:3:4:5                   | $C_4NH.I$                                    | 570.72          | $C_4HNI$             |
| 7     | — methyl ammonium hydroxide               | $(CH_3)_4N.OH$                               | 91.13           | $C_4H_{13}ON$        |
| 8     | — benzene, 1:2:3:4, prehnitol             | $C_6H_2(CH_3)_4$                             | 134.16          | $C_{10}H_{14}$       |
| 9     | — —, 1:2:3:5, $\beta$ iso-durol           | "  | 134.16          | "                    |
| 10    | — —, 1:2:4:5, durol                       | "  | 134.16          | "                    |
| 11    | — diamino benz-hydrol                     | $HO.CH[C_6H_4.N:(CH_3)_2]_2$                 | 270.28          | $C_{17}H_{22}ON_2$   |
| 12    | — — benzophenone                          | $CO[C_6H_4.N:(CH_3)_2]_2$                    | 268.27          | $C_{17}H_{20}ON_2$   |
| 13    | — — diphenyl-amine, 4:4'                  | $NH[C_6H_4.N:(CH_3)_2]_2$                    | 255.28          | $C_{16}H_{21}N_3$    |
| 14    | — — triphenyl methane                     | $C_6H_5.CH[C_6H_4.N:(CH_3)_2]_2$             | 330.35          | $C_{28}H_{26}N_2$    |
| 15    | — methylene diamine                       | $NH_2.(CH_2)_4.NH_2$                         | 88.14           | $C_4H_{12}N_2$       |
| 16    | — methyl succinic acid                    | $C_2(CH_3)_4(COOH)_2$                        | 174.15          | $C_8H_{14}O_4$       |
| 17    | — nitro diphenol, 3:5:3':5':4:4'          | $[C_6H_2(NO_2)_2OH]_2$                       | 366.15          | $C_{12}H_6O_{10}N_4$ |
| 18    | — diphenyl-methane, 2:4:2':4'             | $CH_2[C_6H_3(NO_2)_2]_2$                     | 348.17          | $C_{18}H_8O_8N_4$    |
| 19    | — — methane                               | $C(NO_2)_4$                                  | 196.05          | $CO_4N_4$            |
| 20    | — — naphthalene, $\alpha$                 | $C_{10}H_4(NO_2)_4$                          | 308.12          | $C_{10}H_4O_8N_4$    |
| 21    | — —, $\beta$                              | " "  | 308.12          | " "                  |
| 22    | — phenyl ethane, $\alpha\alpha\beta\beta$ | $(C_6H_5)_2:CH.CH:(C_6H_5)_2$                | 334.31          | $C_{26}H_{22}$       |
| 23    | — — ethylene                              | $(C_6H_5)_2:C:C:(C_6H_5)_2$                  | 332.29          | $C_{26}H_{20}$       |
| 24    | Tetrazole                                 | $\begin{array}{c}   \\ N:N > NH \end{array}$ | 70.06           | $CH_2N_4$            |
| 25    | Tetrolic acid                             | $C_3H_3.COOH$                                | 84.05           | $C_4H_4O_2$          |

| Density<br>$H_2O=1$ . | Solubility in   |                   |            | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------|-----------------|-------------------|------------|-------------|-------------|----|
|                       | Water.          | Alcohol.          | Ether.     |             |             |    |
|                       | s.s.            | s.                | s.s.       | > 380       |             | 1  |
|                       | v.s.s.          | s.s.              | i.         | > 275       | subl.       | 2  |
|                       | v.s.            | v.s.              | s.         | 215—220     |             | 3  |
|                       |                 |                   |            | 148         |             | 4  |
|                       | h.s.            | v.s.              | s.s.       |             |             | 5  |
|                       | i., s. $C_6H_6$ | s.                | v.s.       | d. 140—150  |             | 6  |
|                       | v.s.            |                   |            | d.          |             | 7  |
| 0 8816/90             |                 |                   |            | - 4         | 204         | 8  |
|                       |                 |                   |            | liq.        | 195         | 9  |
|                       | s. $C_6H_6$     | s.                | s.         | 79—80       | 189—191     | 10 |
|                       |                 | s.                | s.         | 96          |             | 11 |
|                       |                 | s.                | s.         | 174         | > 360       | 12 |
|                       |                 | s.                | s. $CS_2$  | 119         |             | 13 |
|                       | i.              | s.                | s.         | 102         |             | 14 |
|                       | s.              |                   |            | 23—24       | 158—160     | 15 |
|                       | 1: 45           | s.                | v.s.       | 190—192     | subl.       | 16 |
|                       | i.              | s.                |            | 225         |             | 17 |
|                       |                 | i.                | i.         | 172         |             | 18 |
|                       | i.              | s.                | s.         | 13          | 126 d.      | 19 |
|                       | c.s.s.          | s. $CHCl_3$       | i.         | 259         | expl.       | 20 |
|                       |                 | s.                |            | 200         | expl.       | 21 |
| 1 182                 | h.s. $C_6H_6$   | s.s., s. $CHCl_3$ | s. acetic. | 209—211     | 358—362     | 22 |
|                       | s. $C_6H_6$     | s.s.              | s.s.       | 227         | 415—425     | 23 |
|                       | s.              | s.                | s.s.       | 156         | subl.       | 24 |
|                       | v.s.            | v.s.s.            | s.         | 76—77       | 203         | 25 |

| Name.                      | Formula.  | Formula Empirical<br>Weight. Formula.                 |
|----------------------------|---|---|
| 1 Thiacetamide             | $\text{CH}_3.\text{CS}.\text{NH}_2$   | 75.12 $\text{C}_2\text{H}_5\text{NS}$                 |
| 2 Thiacetanilide           | $\text{CH}_3.\text{CS}.\text{NH}.\text{C}_6\text{H}_5$  | 151.18 $\text{C}_8\text{H}_9\text{NS}$                |
| 3 Thiacetic acid           | $\text{CH}_3.\text{CO}.\text{SH}$   | 76.10 $\text{C}_2\text{H}_4\text{OS}$                 |
| 4 Thialdin                 | $\text{C}_6\text{H}_{13}\text{NS}_2$  | 163.26 $\text{C}_6\text{H}_{13}\text{NS}_2$           |
| 5 Thianthrene              | $\text{C}_6\text{H}_4:\text{S}_2:\text{C}_6\text{H}_4$  | 216.24 $\text{C}_6\text{H}_4\text{S}_2$               |
| 6 Thiazole                 | $\text{C}_3\text{H}_3\text{NS}$   | 85.11 $\text{C}_3\text{H}_3\text{NS}$                 |
| 7 Thio acetaldehyde        | $(\text{CH}_3.\text{CHS})_3$  | 180.31 $\text{C}_3\text{H}_3\text{S}_3$               |
| 8 — aniline                | $(\text{C}_6\text{H}_4.\text{NH}_2):\text{S}$   | 216.24 $\text{C}_6\text{H}_4\text{N}_2\text{S}$       |
| 9 — benzaldehyde, $\alpha$ | $\text{C}_6\text{H}_5.\text{CHS}$   | 122.14 $\text{C}_7\text{H}_6\text{S}$                 |
| 10 —, $\beta$              | " "   | 122.14 "  |
| 11 — benzoic acid          | $\text{C}_6\text{H}_5.\text{CO}.\text{SH}.\frac{1}{2}\text{H}_2\text{O}$  | 147.15 $\text{C}_7\text{H}_6\text{OS}$                |
| 12 — carbamic acid         | $\text{CS}(\text{NH}_2)\text{SH}$   | 93.16 $\text{CH}_3\text{NS}_2$                        |
| 13 — carbamate, ethyl      | $\text{CS}(\text{NH}_2)\text{SC}_2\text{H}_5$   | 121.20 $\text{C}_3\text{H}_7\text{NS}_2$              |
| 14 — carbanilide           | $\text{CS}(\text{NH}.\text{C}_6\text{H}_5)_2$   | 228.24 $\text{C}_{13}\text{H}_{12}\text{N}_2\text{S}$ |
| 15 — cresol, $o$           | $\text{CH}_3.\text{C}_6\text{H}_4.\text{SH}$  | 124.16 $\text{C}_7\text{H}_8\text{S}$                 |
| 16 —, $m$                  | " "   | 124.16 "  |
| 17 —, $p$                  | " "   | 124.16 "  |
| 18 — cyanic acid           | $\text{NC.S.H.}$  | 59.08 $\text{CHNS}$                                   |
| 19 — cyanate, ethyl        | $\text{NC.S.C}_2\text{H}_5$   | 87.13 $\text{C}_3\text{H}_5\text{NS}$                 |
| 20 —, methyl               | $\text{NC.S.CH}_3$  | 73.10 $\text{C}_2\text{H}_3\text{NS}$                 |
| 21 — cyanuric acid         | $(\text{C.NSH})_3$  | 177.25 $\text{C}_3\text{H}_3\text{N}_3\text{S}_3$     |
| 22 — diphenyl amine, 2:2'  | $\text{S}(\text{C}_6\text{H}_4)_2:\text{NH}$  | 199.20 $\text{C}_{12}\text{H}_9\text{NS}$             |
| 23 — glycollic acid        | $\text{HS}.\text{CH}_2.\text{COOH}$   | 92.10 $\text{C}_2\text{H}_4\text{O}_2\text{S}$        |
| 24 — hydroquinone          | $\text{C}_6\text{H}_4(\text{SH})_2$   | 142.20 $\text{C}_6\text{H}_6\text{S}_2$               |
| 25 — naphthen              | $\text{C}_{10}\text{H}_8 \begin{array}{l} \diagup \text{CH}:\text{CH} \\ \diagdown \quad   \\ \quad \text{S} \end{array}$ | 134.15 $\text{C}_8\text{H}_6\text{S}$                 |
| 26 — oxamide               | $(\text{CS}.\text{NH}_2)_2$   | 120.18 $\text{C}_2\text{H}_4\text{N}_2\text{S}_2$     |
| 27 — oxamine, ethyl        | $\text{NH}_2.\text{CS}.\text{COOC}_2\text{H}_5$   | 133.14 $\text{C}_4\text{H}_7\text{O}_2\text{NS}$      |
| 28 — phenol, see           | Phenyl mercaptan  |   |
| 29 — phosgene              | $\text{CS}:\text{Cl}_2$   | 114.99 $\text{CSCl}_2$                                |
| 30 — resorcinol            | $\text{C}_6\text{H}_4(\text{SH})_2$   | 142.20 $\text{C}_6\text{H}_6\text{S}_2$               |
| 31 — tolene                | $\text{C}_6\text{H}_5.\text{CH}_3.\text{S}$   | 98.13 $\text{C}_7\text{H}_8\text{S}$                  |
| 32 — urea                  | $\text{CS}(\text{NH}_2)_2$  | 76.12 $\text{CH}_4\text{N}_2\text{S}$                 |
| 33 — urethane              | $\text{NH}_2.\text{CO}.\text{S.C}_2\text{H}_5$  | 105.14 $\text{C}_3\text{H}_7\text{ONS}$               |
| 34 Thionine                | $\text{C}_{12}\text{H}_9\text{N}_3\text{S}$   | 227.22 $\text{C}_{12}\text{H}_9\text{N}_3\text{S}$    |
| 35 Thiophen                | $\text{CH}:\text{CH} \begin{array}{l} \diagup \quad \diagdown \\   \quad \quad \quad \text{S} \end{array}$                | 84.11 $\text{C}_4\text{H}_4\text{S}$                  |

| Density<br>$H_2O=1$ . | Solubility in |          |              | M.P.<br>°C. | B.P.<br>°C.  |    |
|-----------------------|---------------|----------|--------------|-------------|--------------|----|
|                       | Water.        | Alcohol. | Ether.       |             |              |    |
|                       | v.s.          |          | s.           | 108.5       |              | 1  |
|                       | i.            | s.       | s. NaOH      | 75          | d.           | 2  |
| 1.074/10°             | s.s.          | s.       | s.           | liq.        | 93           | 3  |
| 1.191                 | s.s.          | 1 : 400  | v.s.         | 43          | d.           | 4  |
|                       | i.            | s.       | s.           | 159         | 364—366      | 5  |
| 1.1998/17°            |               | i.       | s.           | liq.        | 117          | 6  |
|                       | i.            | s.       | i.           | 45—46       | 205          | 7  |
|                       | h.s.          | i.       | s.           | 105         |              | 8  |
|                       | i.            | s.s.     | s. $C_6H_5$  | 160         | d.           | 9  |
|                       |               | m.       | s. acetic    | 225         |              | 10 |
|                       | i.            | s.       | m.           | 24          |              | 11 |
|                       | s.            | v.s.     | s.           |             |              | 12 |
|                       | i.            | s.       | v.s.         | 42          |              | 13 |
| 1.3025/4°             | v.s.s.        |          | s.           | 153         |              | 14 |
|                       | i.            | s.       |              | 15          | 193          | 15 |
| 1.0625/0°             |               |          |              | liq         |              | 16 |
|                       | i.            | s.       |              | 43          | 190.2—191.7  | 17 |
|                       | m.            | m        | s.           | 5           | a. 200       | 18 |
| 1.033/0°              | i.            |          | m.           | liq.        | 132—133      | 19 |
| 1.0126/9°             |               |          |              |             | /753mm.      |    |
| 1.0693/23.8°          |               | v.s.s.   |              | liq.        | 133          | 20 |
|                       | h.v.s.s       | s.s.     | v.s.s.       |             |              | 21 |
|                       |               |          | v.s.         | 180—181     | 371          | 22 |
|                       | m.            | m.       | m.           | - 16.5      | 107—108/15mm | 23 |
|                       |               |          |              | 98          |              | 24 |
|                       |               | s.       |              | 30—31       | 220—221      | 25 |
|                       |               | s.       | s.           | d.          |              | 26 |
|                       | h.s.          | v.s.     | v.s.         | 63          |              | 27 |
|                       |               |          |              |             |              | 28 |
| .5085/15°             | v.s.s.        |          |              |             | 71—74        | 29 |
|                       |               |          |              | 27          | 243          | 30 |
| .0194                 |               |          |              | 13          | 114/738mm    | 31 |
| .42                   | 1 : 11        | v.s.s.   | v.s.s.       | 180         |              | 32 |
|                       | h.s.          | s.       | s.           | 108         | subl.        | 33 |
|                       | v.s.s.        | s.s.     |              |             |              | 34 |
| .0705/15°             | i.            | s.       | s. $H_2SO_4$ | - 37.1      | 84           | 35 |

| Name.                  | Formula.                     | Formula Weight. | Empirical Formula. |
|------------------------|------------------------------|-----------------|--------------------|
| 1 Thiophen alcohol     | $C_4H_3S.CH_2OH$             | 114.13          | $C_5H_6OS$         |
| 2 — aldehyde           | $C_4H_3S.CHO$                | 112.12          | $C_5H_4OS$         |
| 3 — carboxylic acid, 2 | $C_4H_3S.COOH$               | 128.12          | $C_5H_4O_2S$       |
| 4 — — —, 3             | "                            | 128.12          | "                  |
| 5 Thujone              | $C_{10}H_{18}O$              | 154.19          | $C_{10}H_{18}O$    |
| 6 Thymene              | $C_{10}H_{16}$               | 136.18          | $C_{10}H_{16}$     |
| 7 Thymo hydroquinone   | $C_{10}H_{14}O_2$            | 166.16          | $C_{10}H_{14}O_2$  |
| 8 Thymol, 1:3:2        | $C_6H_3(CH_3)(C_3H_7)OH$     | 150.16          | $C_{10}H_{14}O$    |
| 9 —, iso., 3:2:1       | " "                          | 150.16          | "                  |
| 10 Thymoquinone        | $C_{10}H_{12}O_2$            | 164.15          | $C_{10}H_{12}O_2$  |
| 11 Thymotic acid       | $C_6H_2(CH_3)(C_3H_7)(COOH)$ | 194.17          | $C_{11}H_{14}O_3$  |
| 12 — anhydride         | $C_6H_2(CH_3)(C_3H_7)CO.O$   | 176.15          | $C_{11}H_{12}O_2$  |
| 13 Tiglic acid         | $C_5H_8O_2$                  | 100.09          | $C_5H_8O_2$        |
| 14 Tin diethyl         | $Sn(C_2H_5)_2$               | 176.80          | $C_4H_{10}Sn$      |
| 15 — tetraethyl        | $Sn(C_2H_5)_4$               | 234.90          | $C_8H_{20}Sn$      |
| 16 — tetramethyl       | $Sn(CH_3)_4$                 | 178.81          | $C_4H_{12}Sn$      |
| 17 — triethyl          | $Sn(C_2H_5)_3$               | 205.85          | $C_6H_{15}Sn$      |
| 18 Tolane              | $C_6H_5.O : C.C_6H_5$        | 178.15          | $C_{14}H_{10}$     |
| 19 Tolidine, 3:3':4:4' | $(CH_3.C_4H_3NH_2)_2$        | 212.22          | $C_{14}H_{16}N_2$  |
| 20 —, 2:2':4:4'        | " "                          | 212.22          | "                  |
| 21 —, 1:1':4:4''       | " "                          | 212.22          | "                  |
| 22 Toluene             | $C_6H_5.CH_3$                | 92.10           | $C_7H_8$           |
| 23 — sulphamide, o     | $CH_3.C_6H_4.SO_2.NH_2$      | 171.18          | $C_7H_9O_2NS$      |
| 24 — —, m              | " "                          | 171.18          | "                  |
| 25 — —, p              | " "                          | 171.18          | "                  |
| 26 — sulphochloride, o | $CH_3.C_6H_4.SO_2Cl$         | 190.61          | $C_7H_7O_2SCl$     |
| 27 — —, m              | " "                          | 190.61          | "                  |
| 28 — —, p              | " "                          | 190.61          | "                  |
| 29 Toluic acid, o      | $CH_3.C_6H_4.COOH$           | 136.10          | $C_8H_8O_2$        |
| 30 — —, m              | " "                          | 136.10          | "                  |
| 31 — —, p              | " "                          | 136.10          | "                  |
| 32 Toluidine, o        | $CH_3.C_6H_4.NH_2$           | 107.12          | $C_7H_9N$          |
| 33 —, m                | " "                          | 107.12          | "                  |
| 34 —, p                | " "                          | 107.12          | "                  |
| 35 Toluhydroquinone,   | see Dihydroxy toluene        |                 |                    |

| Density<br>$H_2O=1$ . | Solubility in |              |        | M.P.<br>°C. | B.P.<br>°C.  |    |
|-----------------------|---------------|--------------|--------|-------------|--------------|----|
|                       | Water.        | Alcohol.     | Ether. |             |              |    |
| 1.215/21°             |               |              |        | liq.        | 207          | 1  |
|                       |               |              |        |             | 197—198      | 2  |
|                       | h.v.s.        | v.s.         | v.s.   | 126.5       | 260          | 3  |
|                       | s.            |              |        | 136         |              | 4  |
| 0.9126/20°            |               | s.           | s.     |             | 210—212      | 5  |
|                       |               |              |        | liq.        | 160—165      | 6  |
|                       | h.s.          | s.           | s.     | 139.5       | 290          | 7  |
| 0.9941/0°             | 1 : 1200      | s.           | s.     | 50          | 232          | 8  |
|                       |               |              |        | 44          | 228—230      | 9  |
|                       | v.s.s.        | s.           | s.     | 45.5        | 232          | 10 |
|                       | h.s.s.        | s.           | s.     | 127         | sub.         | 11 |
|                       |               |              |        | 174         |              | 12 |
| .654                  | h.v.s.        | s.           | s.     | 64.5        | 198.5        | 13 |
| .187/23°              | i.            | s.           |        | liq.        | d.           | 14 |
| .3138/0°              | i.            |              |        | liq.        | 181/758mm.   | 15 |
| .4115/0°              | i.            | i.           |        | liq.        | 78           | 16 |
|                       |               | s.           | s.     | liq.        | d. 270       | 17 |
|                       | s.s.          | s.           | s.     | 60          |              | 18 |
|                       | h.s.          | s.           | s.     | 128         |              | 19 |
|                       | s.s.          | s.           | s.     | 108—109     |              | 20 |
| .8708/13°             | i.            | s.s.         | s.     | 128—129     |              | 21 |
|                       | 1 : 958/9°    | 1 : 28/5°    |        | - 93.2      | 110.7        | 22 |
|                       | 1 : 376.7/14° | 1 : 5.74/14° |        | 153—154     |              | 23 |
|                       | 1 : 515/9°    | 1 : 13.5/5°  |        | 108         |              | 24 |
|                       |               |              |        | 135—137     |              | 25 |
|                       |               |              |        | F.Pt. 10.0  | 126/10mm.    | 26 |
|                       |               |              |        | F.Pt. 11.7  |              | 27 |
| 0621/115°             | d.            |              |        | 65—66.5     | 145—146/15mm | 28 |
|                       | 0.12 :        | v.s.         |        | 103.5—104   | 259          | 29 |
|                       | 100/25°       |              |        |             |              |    |
| 0543/112°             | 0.1 :         | v.s.         | v.s.   | 111—113     | 263          | 30 |
|                       | 100/25°       |              |        |             |              |    |
|                       | 0.035 :       | v.s.         | v.s.   | 180         | 274—275      | 31 |
|                       | 100/25°       |              |        |             |              |    |
| 9986/20°              |               |              |        | liq.        | 197.7        | 32 |
| 9986/20°              |               |              | s.     | liq.        | 203.3        | 33 |
| 9538/59.1°            | s.s.          | s.           |        | 45          | 200.4        | 34 |
|                       |               |              |        |             |              | 35 |

| Name.                             | Formula.   | Formula Empirical |  |
|-----------------------------------|--|-------------------|--|
|                                   |  | Weight.           | Formula.                                   |
| 1 Toluquinone, 2:1:4              | $\text{CH}_3 \cdot \text{C}_6\text{H}_3 : \text{O}_2$  | 122.08            | $\text{C}_7\text{H}_6\text{O}_2$           |
| 2 Toluyl aldehyde, o              | $\text{CH}_3 \cdot \text{C}_6\text{H}_4 \cdot \text{CHO}$  | 120.10            | $\text{C}_8\text{H}_8\text{O}$             |
| 3 —, m                            | " "  | 120.10            | "  |
| 4 —, p                            | " "  | 120.10            | "  |
| 5 — benzoic acid, 3:3'            | $\text{CH}_3 \cdot \text{C}_6\text{H}_4 \cdot \text{CO} \cdot \text{C}_6\text{H}_4 \cdot \text{COOH}$  | 240.17            | $\text{C}_{15}\text{H}_{12}\text{O}_4$     |
| 6 —, 4:2'                         | $\text{CH}_3 \cdot \text{C}_6\text{H}_3 : (\text{NH}_2)_2$   | 276.20            | $\text{C}_7\text{H}_{10}\text{N}_2$        |
| 7 Toluylene diamine,<br>1:2:3     | $\text{CH}_3 \cdot \text{C}_6\text{H}_3 : (\text{NH}_2)_2$   | 122.14            | "  |
| 8 —, 1:2:4                        | " "  | 122.14            | "  |
| 9 —, 1:2:5                        | " "  | 122.14            | "  |
| 10 —, 1:2:6                       | " "  | 122.12            | $\text{C}_8\text{H}_{10}\text{O}$          |
| 11 Toluyl alcohol, o              | $\text{CH}_3 \cdot \text{C}_6\text{H}_4 \cdot \text{CH}_2\text{OH}$                                    | 122.12            | "  |
| 12 —, m                           | " "  | 122.12            | "  |
| 13 —, p                           | " "  | 140.57            | $\text{C}_8\text{H}_9\text{Cl}$            |
| 14 — chloride, o                  | $\text{CH}_3 \cdot \text{C}_6\text{H}_4 \cdot \text{CH}_2\text{Cl}$                                    | 140.57            | "  |
| 15 —, m                           | " "  | 140.57            | "  |
| 16 —, p                           | " "  | 258.24            | $\text{C}_{20}\text{H}_{18}$               |
| 17 — diphenyl methane, m          | $(\text{C}_6\text{H}_5)_2 : \text{CH} \cdot \text{C}_6\text{H}_4 \cdot \text{CH}_3$                    | 258.24            | "  |
| 18 —, p                           | " "  | 122.14            | $\text{C}_7\text{H}_{10}\text{N}_2$        |
| 19 — hydrazine, o                 | $\text{CH}_3 \cdot \text{C}_6\text{H}_4 \cdot \text{NH} \cdot \text{NH}_2$                             | 122.14            | "  |
| 20 —, m                           | " "  | 122.14            | "  |
| 21 —, p                           | " "  | 196.17            | $\text{C}_{14}\text{H}_{12}\text{O}$       |
| 22 — phenyl ketone, o             | $\text{C}_6\text{H}_5 \cdot \text{CO} \cdot \text{C}_6\text{H}_4 \cdot \text{CH}_3$                    | 196.17            | "  |
| 23 —, p                           | " "  | 143.11            | $\text{C}_6\text{H}_9\text{O}_3\text{N}$   |
| 24 Tri acetamide                  | $\text{N}(\text{C}_2\text{H}_5\text{O})_3$   | 218.16            | $\text{C}_9\text{H}_{14}\text{O}_6$        |
| 25 — acetin                       | $\text{C}_3\text{H}_5(\text{O} \cdot \text{CO} \cdot \text{CH}_3)_3$                                   | 173.21            | $\text{C}_9\text{H}_{17}\text{ON}$         |
| 26 — acetone amine                | $\text{C}_9\text{H}_{17}\text{NO} \cdot \text{H}_2\text{O}$  | 227.21            | $\text{C}_{12}\text{H}_{13}\text{N}_5$     |
| 27 — amino azo benzene,<br>2:4:3' | $\text{NH}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{N}_2 \cdot \text{C}_6\text{H}_3 : (\text{NH}_2)_2$ | 123.13            | $\text{C}_6\text{H}_9\text{N}_3$           |
| 28 — benzene, 1:2:3               | $\text{C}_6\text{H}_3(\text{NH}_2)_3$  | 123.13            | "  |
| 29 —, 1:2:4                       | " "  | 194.17            | $\text{C}_7\text{H}_9\text{O}_2\text{N}_3$ |
| 30 — benzoic acid,<br>3:4:5:1     | $(\text{NH}_2)_3\text{C}_6\text{H}_2 \cdot \text{COOH} \cdot 1\frac{1}{2}\text{H}_2\text{O}$           | 167.14            | "  |
| 31 —, 2:3:5:1                     | " "  | 139.13            | $\text{C}_6\text{H}_9\text{ON}_3$          |
| 32 — phenol                       | $(\text{NH}_2)_3\text{C}_6\text{H}_2\text{OH}$   | 227.35            | $\text{C}_{15}\text{H}_{33}\text{N}^3$     |
| 33 — amyl amine                   | $(\text{C}_5\text{H}_{11})_3\text{N}$  | 69.06             | $\text{C}_2\text{H}_3\text{N}_3$           |
| 34 — azole, 1:2:4                 | $\text{CH} : \text{N} \begin{matrix} \nearrow \text{NH} \\   \\ \text{N} = \text{CH} \end{matrix}$     |                   |  |



| Density<br>$H_2O=1.$ | Solubility in |          |                   | M.P.<br>°C.  | B.P.<br>°C. |    |
|----------------------|---------------|----------|-------------------|--------------|-------------|----|
|                      | Water.        | Alcohol. | Ether.            |              |             |    |
|                      | h.s.          | v.s.     | v.s.              | 67           | subl.       | 1  |
|                      |               |          |                   | liq.         | 200         | 2  |
| 1.024/22°            |               |          |                   | liq.         | 199         | 3  |
| 1.072/12°            |               |          |                   | liq.         | 204         | 4  |
|                      | h.s.s.        | s.       | s.                | 228          | d.          | 5  |
|                      | h.v.s.s.      | v.s.     | v.s.              | 140          | d.          | 6  |
|                      |               | s.       |                   | 61—62        | 255         | 7  |
|                      |               |          |                   | 99           | 280         | 8  |
|                      | s.            | s.       | s., s. $C_6H_6$   | 64           | 273—274     | 9  |
|                      |               | s.       |                   | 103.5—105    |             | 10 |
| 1.023/40°            | s.s.          | s.       | s.                | 31           | 223/750mm.  | 11 |
| 0.9157/17°           | s             |          |                   | liq.         | 217         | 12 |
|                      | h.s.s.        | s.       | s.                | 60           | 217—221     | 13 |
|                      |               |          |                   |              | 197—199     | 14 |
| 1.064/20°            |               |          |                   |              | 195—196     | 15 |
|                      |               |          |                   |              | 192         | 16 |
|                      |               | s.       | s.                | 62           | 353—354.7   | 17 |
|                      |               |          |                   |              | /774mm      |    |
|                      | i.            | h.s.     | s.                | 71           | >360        | 18 |
|                      | s. $CHCl_3$   | s.       | s.                | 56           |             | 19 |
|                      |               |          |                   | liq.         | 240—244     | 20 |
|                      | s. $C_6H_6$   | s.       | s.                | 61           | 240—244     | 21 |
|                      |               |          |                   |              | 315—316     | 22 |
|                      | s. $C_6H_6$   | s.s.     | s.                | 59—60        | 326.5       | 23 |
|                      |               |          | s.                | 78—79        |             | 24 |
| 1.55                 | i.            | m.       | m.                | liq.         | 258—259     | 25 |
|                      | s.            |          | s.                | 58, an. 39.6 |             | 26 |
|                      | h.s.s.        | v.s.     | v.s., s. $C_6H_6$ | 144          |             | 27 |
|                      |               |          |                   |              |             |    |
|                      | v.s.          | v.s.     | v.s.              | 103          | 330         | 28 |
|                      | v.s.          | v.s.     | s.s. $CHCl_3$     | < 100        | 340         | 29 |
|                      | h.s.          | i.       | i.                |              |             | 30 |
|                      |               |          |                   |              |             |    |
|                      | h.s.          | h.v.s.s. | i.                |              |             | 31 |
|                      |               |          |                   |              |             | 32 |
|                      |               |          |                   | liq.         | 257         | 33 |
|                      |               |          |                   |              |             |    |
|                      | s.            | s.       | s.s.              | 120—121      | 260         | 34 |

| Name.                               | Formula.  | Formula Weight. | Empirical Formula.                             |
|-------------------------------------|---|-----------------|--|
| 1 Tri benzoyl methane               | $\text{CH}(\text{CO.C}_6\text{H}_5)_3$              | 328.24          | $\text{C}_{22}\text{H}_{16}\text{O}_3$         |
| 2 — benzyl amine                    | $\text{N}(\text{C}_6\text{H}_5.\text{CH}_2)_3$      | 287.28          | $\text{C}_{21}\text{H}_{21}\text{N}_3$         |
| 3 — brom acetic acid                | $\text{OBr}_3.\text{COOH}$                          | 296.78          | $\text{C}_2\text{H}_3\text{O}_2\text{Br}_3$    |
| 4 — aniline, 2 : 4 : 6              | $\text{C}_6\text{H}_2(\text{Br}_3)\text{NH}_2$      | 329.83          | $\text{C}_6\text{H}_4\text{NBr}_3$             |
| 5 — benzene, 1 : 2 : 3              | $\text{C}_6\text{H}_3\text{Br}_3$                   | 314.81          | $\text{C}_6\text{H}_3\text{Br}_3$              |
| 6 — —, 1 : 3 : 4                    | "   | 314.81          | "  |
| 7 — —, 1 : 3 : 5                    | "   | 314.81          | "  |
| 8 — hydrin                          | $\text{CH}_2\text{Br.CHBr.CH}_2\text{Br}$           | 280.82          | $\text{C}_3\text{H}_5\text{Br}_3$              |
| 9 — phenol, 2 : 4 : 6               | $\text{C}_6\text{H}_2\text{OH}(\text{Br}_3)$        | 330.81          | $\text{C}_6\text{H}_3\text{OBr}_3$             |
| 10 — resorcinol, 2 : 4 : 3          | $\text{C}_6\text{H}(\text{OH})_2(\text{Br}_3)$      | 346.81          | $\text{C}_6\text{H}_3\text{O}_2\text{Br}_3$    |
| 11 — butyl amine                    | $(\text{C}_4\text{H}_9)_3\text{N}$                  | 185.29          | $\text{C}_{12}\text{H}_{27}\text{N}_3$         |
| 12 — carballylic acid               | $\text{C}_3\text{H}_5(\text{COOH})_3$               | 176.09          | $\text{C}_9\text{H}_8\text{O}_6$               |
| 13 — chlor acetal, 1                | $\text{CHCl}_2.\text{CCl}(\text{OC}_2\text{H}_5)_2$ | 221.50          | $\text{C}_6\text{H}_{11}\text{O}_2\text{Cl}_3$ |
| 14 — —, 2                           | $\text{CCl}_3.\text{CH}(\text{OC}_2\text{H}_5)_3$   | 221.50          | "  |
| 15 — acetamide                      | $\text{CCl}_3.\text{CO.NH}_2$                       | 162.42          | $\text{C}_2\text{H}_2\text{ONCl}_3$            |
| 16 — acetic acid                    | $\text{CCl}_3.\text{COOH}$                          | 163.40          | $\text{C}_2\text{H}_2\text{OCl}_3$             |
| 17 — acetate, ethyl                 | $\text{CCl}_3.\text{COO.C}_2\text{H}_5$             | 191.44          | $\text{C}_4\text{H}_5\text{O}_2\text{Cl}_3$    |
| 18 — aniline, 1 : 2 : 3 : 4         | $\text{NH}_2.\text{C}_6\text{H}_2\text{Cl}_3$       | 196.45          | $\text{C}_6\text{H}_4\text{NCl}_3$             |
| 19 — —, 1 : 2 : 4 : 5               | " "   | 196.45          | "  |
| 20 — —, 1 : 2 : 4 : 6               | " "   | 196.45          | "  |
| 21 — benzene, 1 : 2 : 3             | $\text{C}_6\text{H}_3.\text{Cl}_3$                  | 181.43          | $\text{C}_6\text{H}_3\text{Cl}_3$              |
| 22 — —, 1 : 2 : 4                   | "   | 181.43          | "  |
| 23 — —, 1 : 3 : 5                   | "   | 181.43          | "  |
| 24 — benzoic acid,<br>1 : 2 : 4 : 5 | $\text{HOOC.C}_6\text{H}_2\text{Cl}_3$              | 225.44          | $\text{C}_7\text{H}_3\text{O}_2\text{Cl}_3$    |
| 25 — — —, 1 : 2 : 3 : 4             | " "   | 225.44          | "  |
| 26 — — —, 1 : 3 : 4 : 5             | " "   | 225.44          | "  |
| 27 — ethane, $\alpha \alpha \beta$  | $\text{CH}_2\text{Cl.CHCl}_2$                       | 133.41          | $\text{C}_2\text{H}_3\text{Cl}_3$              |
| 28 — —, methyl<br>chloroform        | $\text{CH}_3.\text{CCl}_3$                          | 133.41          | "  |
| 29 — ethylene                       | $\text{C}_2\text{HCl}$                              | 131.40          | $\text{C}_2\text{HCl}$                         |
| 30 — hydrin                         | $\text{CH}_2\text{Cl}_3.\text{CHCl.CH}_2\text{Cl}$  | 147.44          | $\text{C}_2\text{H}_5\text{Cl}_3$              |
| 31 — hydroquinone                   | $\text{C}_6\text{HCl}(\text{OH})_2 (2 : 3 : 5)$     | 213.43          | $\text{C}_6\text{H}_5\text{O}_2\text{Cl}_3$    |
| 32 — lactic acid                    | $\text{CCl}_3.\text{CHOH.COOH}$                     | 193.42          | $\text{C}_3\text{H}_5\text{O}_3\text{Cl}_3$    |
| 33 — phenol, 1 : 2 : 4 : 6          | $\text{OH.C}_6\text{H}_2\text{Cl}_3$                | 197.43          | $\text{C}_6\text{H}_3\text{OCl}_3$             |
| 34 — —, 1 : 2 : 3 : 5               | "   | 197.43          | "  |
| 35 — quinone, 2 : 3 : 5             | $\text{C}_6\text{HO}_2(\text{Cl}_3)$                | 211.42          | $\text{C}_6\text{HO}_2\text{Cl}_3$             |

| Density<br>$H_2O=1$ . | Water.    | Solubility in—<br>Alcohol. Ether. |                 | M.P.<br>°C. | B.P.<br>°C. |    |
|-----------------------|-----------|-----------------------------------|-----------------|-------------|-------------|----|
|                       | s. $OS_2$ | v.s.s.                            | v.s.s.          | 223—226     | subl.       | 1  |
|                       | v.s.s.    | h.s.                              | s.              | 91          |             | 2  |
|                       | s.        | s.                                |                 | 135         | d. 245      | 3  |
|                       |           |                                   |                 | 122         | 300         | 4  |
|                       |           | s.                                |                 | 87.4        |             | 5  |
|                       |           | s.s.                              |                 | 44          | 275—276     | 6  |
|                       |           | h.s.s.                            |                 | 119.6       | 278         | 7  |
| 2.436/23°             |           |                                   |                 | 16          | 219—221     | 8  |
|                       | v.s.s.    | v.f                               |                 | 94          | subl.       | 9  |
| 0.7782/20°            | h.s.s.    | s.                                |                 | 112         |             | 10 |
|                       |           |                                   |                 | 171         | 211—215     | 11 |
|                       |           |                                   |                 |             | /740mm      |    |
|                       | s.        | s.                                | s.s.            | 165         |             | 12 |
|                       |           | s.                                | s.              | 83          | 230         | 13 |
| 1.288                 | v.s.s.    | m.                                | m.              | liq.        | 199—205     | 14 |
|                       | h.s.s.    | s                                 | s.              | 141         | 238—239     | 15 |
| 1.63/61°              | v.s.      | s.                                | s.              | 57          | 196—197     | 16 |
| 1.369/15°             | i.        |                                   |                 | liq.        | 164         | 17 |
|                       |           |                                   |                 | 67.5        | 292         | 18 |
|                       |           |                                   |                 | 95—96       | 270         | 19 |
|                       |           | s.                                | s.              | 77          | 262         | 20 |
|                       |           | s.s.                              |                 | 53—54       | 218—219     | 21 |
| 1.574/10°             |           |                                   |                 | 16          | 213         | 22 |
| { solid.              |           |                                   |                 |             |             |    |
| 1.466/10° liq         |           |                                   |                 |             |             |    |
|                       | h.s.      | s.                                |                 | 63.4        | 208.5       | 23 |
|                       |           |                                   |                 | 163         | subl.       | 24 |
|                       | v.s.      |                                   |                 | 129         |             | 25 |
|                       | v.s.s.    | s.                                | s., s. $C_6H_6$ | 203         | subl.       | 26 |
| 1.4406/25.5°          |           |                                   |                 |             | 114         | 27 |
| 1.3249/26°            |           |                                   |                 |             | 74          | 28 |
|                       |           |                                   |                 |             | 88          | 29 |
| 1.417/15°             |           |                                   |                 | liq.        | 154—156     | 30 |
|                       | h.s.      | s.                                | s.              | 134         |             | 31 |
|                       | s.        | s.                                | s.              | 115—118     |             | 32 |
|                       | v.s.s.    | v.s.                              | v.s.            | 68          | 243.5—244.5 | 33 |
|                       | h.s.      | s.                                | s.              | 53—54       | 252—253     | 34 |
|                       | v.s.s.    | h.s.                              | s.              | 165—166     |             | 35 |

| Name.                    | Formula.                             | Formula Weight. | Empirical Formula.  |
|--------------------------|--------------------------------------|-----------------|---------------------|
| 1 Tri decane             | $C_{13}H_{28}$                       | 184.29          | $C_{13}H_{28}$      |
| 2 —decylene              | $C_{13}H_{26}$                       | 182.27          | $C_{13}H_{26}$      |
| 3 —ethyl amine           | $(C_2H_5)_3N$                        | 101.16          | $C_6H_{15}N$        |
| 4 ——arsine               | $(C_2H_5)_3As$                       | 162.11          | $C_6H_{15}As$       |
| 5 ——benzene, 1:3:5       | $C_6H_3(C_2H_5)_3$                   | 162.20          | $C_6H_{15}$         |
| 6 ——phosphine            | $(C_2H_5)_3P$                        | 118.19          | $C_6H_{15}P$        |
| 7 ——oxide                | $(C_2H_5)_3PO$                       | 134.19          | $C_6H_{15}OP$       |
| 8 ——sulphide             | $(C_2H_5)_3PS$                       | 150.25          | $C_6H_{15}SP$       |
| 9 ——silicol              | $(C_2H_5)_3Si.OH$                    | 132.3           | $C_6H_{16}OSi$      |
| 10 ——ester               | $(C_2H_5)_3Si.OO^2H_5$               | 160.3           | $C_9H_{20}OSi$      |
| 11 ——oxide               | $Si.(C_2H_5)_6O$                     | 246.5           | $C_{12}H_{30}OSi_2$ |
| 12 —ethylene diamine     | $(C_2H_4)_3N_2$                      | 112.15          | $C_6H_{12}N_2$      |
| 13 —hydroxy benzene,     | 1:2:4, see Hydroxy hydroquinone      |                 |                     |
| 14 ——anthraquinone       |                                      |                 |                     |
| 15 1. Anthragallol       | $C_{14}H_5O_2(OH)_3.H_2O$            | 256.13          | $C_{14}H_8O_5$      |
| 16 2. Purpurin           | " " .H <sub>2</sub> O                | 274.15          | "                   |
| 17 3. Anthrapurpurin     | " "                                  | 256.13          | "                   |
| 18 4. Flavopurpurin      | " "                                  | 256.13          | "                   |
| 19 —benzoic acid,        | $C_6H_2(OH)_3COOH (\frac{1}{3}H_2O)$ | 170.08          | $C_7H_6O_5$         |
| 2:3:4:1                  |                                      |                 |                     |
| 20 —benzo phenone        | $C_{13}H_{10}O_4$                    | 230.15          | $C_{13}H_{10}O_4$   |
| 21 —methylene, $\alpha$  | $C_3H_6O_3$                          | 90.06           | $C_3H_6O_3$         |
| 22 —pyridine, 2:4:6      | $C_5H_2N(OH)_3$                      | 127.08          | $C_5H_5O_3N$        |
| 23 —iodo benzene, 1:2:3  | $C_6H_3I_3$                          | 455.81          | $C_6H_3I_3$         |
| 24 ——, 1:2:4             | "                                    | 455.81          | "                   |
| 25 ——, 1:3:5             | $C_6H_3I_3$                          | 455.81          | $C_6H_3I_3$         |
| 26 —mellitic acid, 1:2:4 | $C_6H_3(COOH)_3$                     | 210.09          | $C_9H_6O_6$         |
| 27 —mesic acid, 1:4:5    | " "                                  | 210.09          | "                   |
| 28 —methyl acetic acid   | $(CH_3)_3C.COOH$                     | 102.10          | $C_5H_{10}O_2$      |
| 29 —amine                | $(CH_3)_3N$                          | 59.10           | $C_3H_9N$           |
| 30 —arsine               | $(CH_3)_3As$                         | 120.05          | $C_3H_9As$          |
| 31 —benzene, 1:2:3       | $C_6H_3(CH_3)_3$                     | 120.14          | $C_9H_{12}$         |
| 32 —benzoic acid,        | $(CH_3)_3C_6H_2.COOH$                | 165.15          | $C_{10}H_{12}O_2$   |
| 1:3:5:2                  |                                      |                 |                     |
| 33 —cyclo hexane, see    | Hexa hydro cumene                    |                 |                     |
| 34 —ethylene             | $(OH)_2:C.CH.CH_3$                   | 70.10           | $C_5H_{10}$         |
| 35 —phosphine            | $(OH)_3P$                            | 76.13           | $C_3H_9P$           |
| 36 —quinoline, 2:3:4     | $C_{12}H_{13}N$                      | 171.17          | $C_{12}H_{13}N$     |
| 37 ——, 2:5:7             | "                                    | 171.17          | "                   |
| 38 ——, 2:3:6             | "                                    | 171.17          | "                   |

| Density<br>$H_2O=1.$ | Solubility in |          |                 | M.P.<br>°C. | B.P.<br>°C. |    |
|----------------------|---------------|----------|-----------------|-------------|-------------|----|
|                      | Water.        | Alcohol. | Ether.          |             |             |    |
| 0.7608/15°           |               |          |                 | - 6.2       | 234         | 1  |
| 0.8445/0°            |               |          |                 |             | 232.7       | 2  |
| 0.7331/15°           | s.s.          | s.       |                 | liq         | 89          | 3  |
| 1.151/17°            | i.            |          |                 | liq.        | 140/736mm.  | 4  |
|                      |               |          |                 |             | 217—220     | 5  |
| 0.812/15°            | i.            | s.       | s.              | liq.        | 127.5/744   | 6  |
|                      |               | m.       | m.              | 52.9        | 242.9       | 7  |
|                      |               |          |                 | 95          | subl. 120   | 8  |
|                      |               |          |                 |             | -145        |    |
| 0.8709/0°            | i.            |          |                 | liq.        | 154         | 9  |
| 0.8403/0°            |               |          |                 | liq.        | 153         | 10 |
| 0.859/0°             |               |          |                 | liq.        | 231         | 11 |
|                      |               |          |                 | liq.        | 210         | 12 |
|                      |               |          |                 |             |             | 13 |
|                      |               |          |                 |             |             | 14 |
|                      | v.s.s.        | s.       | s.              | 310         | subl. 290   | 15 |
|                      | s.s.          | s.       | s., s. $C_6H_6$ | 256         | subl. 150   | 16 |
|                      | h.s.s.        | h.s.     | s.s.            | 369         | 462         | 17 |
|                      | h.s.s.        | s.       | s.s.            | > 330       | 459         | 18 |
| 1.694/4°             | h.s.          | s.       | v.s.            | an. 110     |             | 19 |
|                      |               | h.s.     | s. $C_6H_6$     | 133—134     |             | 20 |
|                      | s.            | s.       | i.              | 152         | subl.       | 21 |
|                      | s.s.          | i.       | i.              | 220—230 d.  |             | 22 |
|                      |               | s.       |                 | 116         | subl.       | 23 |
|                      |               |          |                 | 91.4        |             | 24 |
|                      |               |          |                 | 182—184     |             | 25 |
|                      | v.s.          |          | v.s.            | 215—217     |             | 26 |
|                      | h.s.          | v.s.     | s.              | 345—350     | subl.       | 27 |
| 0.905/50°            | 1: 45/20°     |          |                 | 38          | 162—164     | 28 |
| 0.673/0°             | v.s.          | v.s.     |                 |             | 3.2—3.8     | 29 |
|                      | s.s.          |          |                 |             | 70          | 30 |
| 0.8694/10°           |               |          |                 |             | 175—175.5   | 31 |
|                      | h.s.s.        | v.s.     | v.s.            | 152         |             | 32 |
|                      |               |          |                 |             |             | 33 |
| 0.6783/0°            |               |          |                 |             | 36.4—37.2   | 34 |
| > $H_2O$             | i.            |          |                 | liq.        | 40—42       | 35 |
|                      |               |          |                 | 65          | 285         | 36 |
|                      | s.            | v.s.     | s.s.            | 43          | 285—287     | 37 |
|                      |               | s.       | s.              | 86—87       | 285         | 38 |

| Name.                                  | Formula.   | Formula Weight. | Empirical Formula. |
|--|--|-----------------|--------------------|
| 1 Tri methyl quinoline,<br>2:6:8       | $C_{12}H_{13}N$  | 171.17          | $C_{12}H_{13}N$    |
| 2 ———, 2:4:6                           | "  | 171.17          | "                  |
| 3 — methylene bromide                  | $CH_2Br.CH_2.CH_2Br$   | 201.90          | $C_3H_6Br_2$       |
| 4 — — diamine                          | $NH_2.(CH_2)_3.NH_2$   | 74.12           | $C_3H_{10}N_2$     |
| 5 — — dicarboxylic<br>acid             | $CH_2 \begin{matrix} \diagup \\ \diagdown \end{matrix} C:(COOH)_2$ | 130.07          | $C_5H_6O_4$        |
| 6 — — glycol                           | $CH_2OH.CH_2.CH_2OH$   | 76.08           | $C_3H_8O_2$        |
| 7 — — sulphide                         | $C_3H_6S_3$  | 138.24          | $C_3H_6S_3$        |
| 8 — nitro aceto-<br>nitrile            | $C(NO_2)_3.CN$   | 86.10           | $C_2O_6N_4$        |
| 9 — — aniline, see                     | Picramide  |                 |                    |
| 10 — — benzene, 1:3:5                  | $C_6H_3(NO_2)_3$   | 213.08          | $C_6H_3O_6N_3$     |
| 11 — — naphthalene,<br>1:3:5           | $C_{10}H_5(NO_2)_3$  | 263.12          | $C_{10}H_5O_6N_3$  |
| 12 — — —, 1:3:8                        | " "  | 263.12          | "                  |
| 13 — — —, 1:4:5                        | " "  | 263.12          | "                  |
| 14 — — orcinol                         | $C_6(NO_2)_3(CH_3)(OH)_2$  | 259.10          | $C_7H_5O_8N_3$     |
| 15 — — phenol, 1:2:4:6,<br>picric acid | $OH.C_6H_2(NO_2)_3$  | 229.08          | $C_6H_3O_7N_3$     |
| 16 — — —, 1:3:4:6                      | " "  | 229.08          | "                  |
| 17 — — —, 1:2:3:6                      | " "  | 229.08          | "                  |
| 18 — — resorcinol                      | $C_6H(NO_2)_3(OH)_2$   | 245.08          | $C_6H_3O_8N_3$     |
| 19 — — toluene, 1:2:4:6                | $CH_3.C_6H_2(NO_2)_3$  | 227.10          | $C_7H_5O_6N_3$     |
| 20 — — —, 1:3:4:6                      | " "  | 227.10          | "                  |
| 21 — — —, $\beta$                      | " "  | 227.10          | "                  |
| 22 — — xylene,<br>2:4:6:1:3            | $C_6H(NO_2)_3(CH_3)_2$   | 241.13          | $C_8H_7O_6N_3$     |
| 23 — — —, 2:3:5:1:4                    | " "  | 241.13          | "                  |
| 24 — phenyl acetic acid                | $(C_6H_5)_3:C.COOH$  | 288.23          | $C_{20}H_{16}O_2$  |
| 25 — — amine                           | $(C_6H_5)_3N$  | 245.22          | $C_8H_{15}N$       |
| 26 — — benzene, 1:3:5                  | $C_6H_3(C_6H_5)_3$   | 306.26          | $C_8H_{15}N$       |
| 27 — — carbinol                        | $(C_6H_5)_3COH$  | 260.22          | $C_{19}H_{16}O$    |
| 28 — — dihydro<br>glyoxaline           | $C_6H_5.CH.NH \begin{matrix}   \\ \diagup \end{matrix} C_6H_5$     | 298.27          | $C_{21}H_{18}N_2$  |
| 29 — — guanidine, $\alpha$             | $C_6H_5.N:C:(NH.C_6H_5)_2$   | 287.17          | $C_{19}H_{17}N_3$  |
| 30 — — —, $\beta$                      | " "  | 287.17          | "                  |

| Density<br>$H_2O=1.$ | Solubility in   |                  |                 | M.P.<br>°C. | B.P.<br>°C. |    |
|----------------------|-----------------|------------------|-----------------|-------------|-------------|----|
|                      | Water.          | Alcohol.         | Ether.          |             |             |    |
| 1.973/17°            | l.              | v.s.             | s.              | 45—46       | 266—267     | 1  |
|                      | s.              |                  |                 | 63—64       | /780mm.     | 2  |
|                      |                 |                  |                 | liq.        | 277—278     | 3  |
|                      |                 | m.               | m.              |             | 160—163     | 4  |
| 1.0526/18°           | v.s.            |                  | s.              | 139         | /719mm.     | 5  |
|                      | m.              |                  |                 | liq.        | 216         | 6  |
|                      | h.s.s.          | s.s.             | s.s.            | 216         | subl.       | 7  |
|                      | d.              | d.               | s.              | 41.5        |             | 8  |
| 1.767/19°            | h.s.            | h.s.             | s., s. $C_6H_6$ | 122         | d.          | 9  |
|                      | s. acetic.      | s.               | s. $CHCl_3$     | 122         |             | 10 |
|                      | v.s.s. $CHCl_3$ | v.s.s.           | v.s.s.          | 218         |             | 11 |
|                      | s.s. $C_6H_6$   | s.s.             | s.s.            | 154         |             | 12 |
|                      | h.s.            | s. $C_6H_6$      | s.s.            | 163.5       |             | 13 |
|                      | 1.525 :         | s.               | s.              | 122.5       | subl. expl. | 14 |
|                      | 100/30°         |                  |                 |             |             | 15 |
|                      | h.s.            | v.s.             | v.s.            | 96          |             | 16 |
|                      | h.s.            | v.s.             | v.s.            | 117—118     |             | 17 |
|                      | s.s.            | s.               | s.              | 175.5       | subl.       | 18 |
|                      | h.s.            | h.s.             |                 | 80.8—80.85  |             | 19 |
|                      | s. acetone.     | v.s.s.           | s., s. $C_6H_6$ | 104         |             | 20 |
|                      | s. acetone.     | hs., s. $C_6H_6$ | s., s. $CS_2$   | 112         |             | 21 |
|                      |                 | h.s.s.           |                 | 182         |             | 22 |
| 1.206                |                 | h.v.s.           |                 | 139—140     |             | 23 |
|                      |                 | s.s.             |                 | 267 d.      |             | 24 |
|                      |                 | s.s.             | s. $C_6H_6$     | 127         | 347—348     | 25 |
|                      | s. $C_6H_6$     | s.s. (50%)       | s.s.            | 170         | >300        | 26 |
|                      |                 | s.               | s.              | 162.5       | >360        | 27 |
|                      |                 | s.               | s.              | 113,        |             | 28 |
|                      |                 |                  |                 | iso. 198    |             |    |
|                      | h.v.s.s.        | s.               |                 | 143         | d.          | 29 |
|                      | v.s.s.          | s.               | s.              | 311         |             | 30 |

| Name.                     | Formula.   | Formula Weight. | Empirical Formula.   |
|---------------------------|--|-----------------|----------------------|
| 1 Tri phenyl methane      | $(C_6H_5)_3OH$   | 244.22          | $C_{19}H_{16}$       |
| 2 ——— carboxylic acid     | $(C_6H_5)_2 : CH.C_6H_4.COOH$  | 288.22          | $C_{20}H_{16}O_2$    |
| 3 ——— oxazole             | $C_6H_5.C \begin{cases} O.O.C_6H_5 \\ N.O.C_6H_5 \end{cases}$                            | 297.24          | $C_{21}H_{15}ON$     |
| 4 — quinonyl              | $C_6H_5O^{14}$   | 312.16          | $C_6H_5O^{14}$       |
| 5 — thiocarbonic acid     | $CS(SH)_2$   | 110.20          | $CH_2S_3$            |
| 6 Tropic acid, <i>i</i>   | $C_6H_5.CH(COOH).CH_2OH$   | 166.13          | $C_9H_{10}O_3$       |
| 7 —, <i>d</i>             | " "  | 166.13          | "                    |
| 8 —, <i>l</i>             | " "  | 166.13          | "                    |
| 9 Tropidine               | $C_8H_{13}N$   | 123.15          | $C_8H_{13}N$         |
| 10 Tryptophan             | $C_6H_4.C.CH_2.CH.NH_2$<br>                    <br>NH—CH        COOH                     | 204.17          | $C_{11}H_{12}O_2N_2$ |
| 11 Tyrosine, <i>o</i>     | $OH.C_6H_4.C_2H_3(NH_2)COOH$   | 181.14          | $C_9H_{11}O_3N$      |
| 12 —, <i>m</i>            | " "  | 181.14          | "                    |
| 13 —, <i>d</i>            | " "  | 181.14          | "                    |
| 14 —, <i>l</i>            | " "  | 181.14          | "                    |
| 15 Umbellic acid          | $C_9H_8O^4$  | 180.00          | $C_9H_8O^4$          |
| 16 Umbelliferone          | $C_9H_6O^3$  | 162.09          | $C_9H_6O^3$          |
| 17 Undecane               | $CH_3.(CH_2)_9.CH_3$   | 156.25          | $C_{11}H_{24}$       |
| 18 Uramil                 | $CO \begin{cases} NH.CO \\ NH.CO \end{cases} CH.NH_2$                                    | 143.09          | $C_4H_5O_3N_3$       |
| 19 Urea                   | $CO : (NH_2)_2$  | 60.06           | $CH_4ON_2$           |
| 20 Urethane               | $CO(NH_2)OC_2H_5$<br>NH.CO   | 89.08           | $C_3H_7O_2N$         |
| 21 Uric acid              | $CO.C.NH \begin{cases} NH.CO \\ NH.CO \end{cases} CO$<br>                    <br>NH.C.NH | 168.10          | $C_5H_4O_3N_4$       |
| 22 Urotropine, see        | Hexamethylene tetramine  |                 |                      |
| 23 Usnic acid, <i>d</i>   | $C_{18}H_{16}O_7$  | 344.22          | $C_{18}H_{16}O_7$    |
| 24 —, <i>l</i>            | " "  | 344.22          | "                    |
| 25 Uvitic acid, 1 : 3 : 5 | $CH_3.C_6H_3 : (COOH)_2$   | 180.11          | $C_9H_8O_4$          |
| 26 —, <i>iso</i> .        | " "  | 180.11          | "                    |
| 27 Uvitic acid            | $CH_3.C_5H_2N : (COOH)_2$  | 181.11          | $C_8H_7O_4N$         |



| Density<br>$H_2O=1.$      | Solubility in   |          |             | M.P.<br>°C. | B.P.<br>°C. |    |
|---------------------------|-----------------|----------|-------------|-------------|-------------|----|
|                           | Water.          | Alcohol. | Ether.      |             |             |    |
| 1.0166/95°                | h.s. $C_6H_6$   | h.s.     | s.          | 94—95       | 358—359     | 1  |
|                           | i.              | s.       | s.          | 162         | /754mm.     | 2  |
|                           |                 | s.       | s.          | 115         |             | 3  |
|                           | h.s.            | i.       | i.          | 95 d.       |             | 4  |
|                           | i.              |          |             | liq.        |             | 5  |
|                           | s.              | s.       | s.          | 117—118     | d.          | 6  |
|                           |                 |          |             | 127—128     |             | 7  |
|                           |                 |          |             | 123         |             | 8  |
| { 0.9467/19°<br>0.9665/0° | c.s.,<br>h.s.s. | v.s.     | v.s.        | liq.        | 162—163     | 9  |
|                           | s.              | i.       | i.          | 289         |             | 10 |
| 1.456                     | h.s.            | v.s.s.   | i.          | 249—250     |             | 11 |
|                           |                 |          |             | 280—281     |             | 12 |
|                           |                 |          |             | 310—314     |             | 13 |
|                           | h.s.            | s.       | i.          | 295 d.      |             | 14 |
|                           | h.s.            | s.       | s.s.        | d. 125      |             | 15 |
| { 0.756/0°<br>0.7448/15°  |                 |          |             | 223—224     | subl.       | 16 |
|                           |                 |          |             | 26.5        | 194         | 17 |
|                           | h.s.s.          |          | s. $NH_4OH$ |             |             | 18 |
| 1.323                     | 1:1             | 1:20     | s.s.        | 132—133     | d.          | 19 |
| 0.9862/21°                | s.              | s.       | s.          | 49—50       | 184         | 20 |
| 1.855—1.893               | v.s.s.          | i.       | i.          | d.          | d.          | 21 |
|                           | i.              | s.s.     | s.          | 195—196     | d.          | 22 |
|                           |                 |          |             | 197—198     |             | 23 |
|                           | h.v.s.s.        | s.       | s.          | 274         | ubl.        | 24 |
|                           | h.s.            | s.       | s.          | 175         |             | 25 |
|                           | v.s.s.          | s. a.o.  | s. aniline  | 274 d.      |             | 26 |
|                           |                 |          |             |             |             | 27 |

| Name.                             | Formula.   | Formula Weight. | Empirical Formula.                         |
|-----------------------------------|--|-----------------|--|
| 1 Valeraldehyde, norm.            | $\text{CH}_3(\text{CH}_2)_3\text{CHO}$   | 86.11           | $\text{C}_5\text{H}_{10}\text{O}$          |
| 2 —, iso.                         | $(\text{CH}_3)_2:\text{CH}\cdot\text{CH}_2\text{CHO}$  | 86.11           | "  |
| 3 Valeramide                      | $\text{C}_4\text{H}_9\cdot\text{CO}\cdot\text{NH}_2$   | 101.12          | $\text{C}_5\text{H}_{11}\text{ON}$         |
| 4 Valeric acid, 1, norm.          | $\text{CH}_3(\text{CH}_2)_3\cdot\text{COOH}$   | 102.10          | $\text{C}_5\text{H}_{10}\text{O}_2$        |
| 5 —, 2, Iso propyl<br>acetic acid | $(\text{CH}_3)_2:\text{CH}\cdot\text{CH}_2\cdot\text{COOH}$  | 102.10          | "  |
| 6 —, 3, Pivalic acid, see         | Trimethyl acetic acid  |                 |  |
| 7 Valerate, iso, iso amyl         | $\text{C}_4\text{H}_9\cdot\text{COO}\cdot\text{C}_5\text{H}_{11}$  | 172.21          | $\text{C}_{10}\text{H}_{20}\text{O}_2$     |
| 8 —, —, ethyl                     | $\text{C}_4\text{H}_9\cdot\text{COO}\cdot\text{C}_2\text{H}_5$   | 130.15          | $\text{C}_7\text{H}_{14}\text{O}_2$        |
| 9 —, methyl                       | $\text{C}_4\text{H}_9\cdot\text{COO}\cdot\text{CH}_3$  | 116.13          | $\text{C}_6\text{H}_{12}\text{O}_2$        |
| 10 Valeric anhydride              | $(\text{C}_4\text{H}_9\cdot\text{CO})_2\text{O}$   | 186.19          | $\text{C}_{10}\text{H}_{18}\text{O}_3$     |
| 11 Valerylene                     | $(\text{CH}_3)_2:\text{C}:\text{C}:\text{CH}_2$  | 68.09           | $\text{C}_5\text{H}_8$                     |
| 12 Vanillic acid                  | $\text{C}_6\text{H}_3(\text{OCH}_3)(\text{OH})\text{COOH}$   | 168.10          | $\text{C}_8\text{H}_8\text{O}_4$           |
| 13 — alcohol                      | $\text{C}_6\text{H}_3(\text{OCH}_3)(\text{OH})\text{CH}_2\text{OH}$  | 154.12          | $\text{C}_8\text{H}_{10}\text{O}_3$        |
| 14 Vanillin, 3:1:4                | $\text{C}_6\text{H}_3(\text{OCH}_3)(\text{OH})\text{CHO}$  | 152.10          | $\text{C}_8\text{H}_8\text{O}_3$           |
| 15 Veratrol                       | $\text{C}_6\text{H}_4:(\text{OCH}_3)_2$  | 138.12          | $\text{C}_8\text{H}_{10}\text{O}_2$        |
| 16 Vinyl amine                    | $\text{C}_2\text{H}_3\cdot\text{NH}_2$   | 43.06           | $\text{C}_2\text{H}_5\text{N}$             |
| 17 — bromide                      | $\text{CH}_2:\text{CHBr}$  | 106.95          | $\text{C}_2\text{H}_3\text{Br}$            |
| 18 — chloride                     | $\text{CH}_2:\text{CHCl}$  | 62.49           | $\text{C}_2\text{H}_3\text{Cl}$            |
| 19 — sulphide                     | $(\text{C}_2\text{H}_3)_2\text{S}$   | 86.13           | $\text{C}_4\text{H}_6\text{S}$             |
| 20 Violuric acid                  | $\text{CO} \begin{array}{c} \diagup \text{NH}\cdot\text{CO} \\ \diagdown \text{NH}\cdot\text{CO} \end{array} \text{C}:\text{NOH} \cdot \text{H}_2\text{O}$ | 175.09          | $\text{C}_4\text{H}_3\text{O}_4\text{N}_3$ |
| 21 Xanthene                       | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{CH}_2 \\ \diagdown \text{O} \end{array} \text{C}_6\text{H}_4$   | 182.15          | $\text{C}_{13}\text{H}_{10}\text{O}$       |
| 22 Xanthogen amide                | $\text{CS}(\text{OC}_2\text{H}_5)\text{NH}_2$  | 105.14          | $\text{C}_5\text{H}_9\text{ONS}$           |
| 23 Xanthogenic acid               | $\text{CS}(\text{OC}_2\text{H}_5)\text{SH}$  | 122.18          | $\text{C}_5\text{H}_7\text{OS}_2$          |
| 24 Xanthogenate, ethyl            | $\text{CS}(\text{OC}_2\text{H}_5)_2\text{S}\cdot\text{O}_2\text{H}_8$  | 150.23          | $\text{C}_5\text{H}_{10}\text{OS}_2$       |
| 25 Xanthone                       | $\text{C}_6\text{H}_4 \begin{array}{c} \diagup \text{CO} \\ \diagdown \text{O} \end{array} \text{C}_6\text{H}_4$   | 196.13          | $\text{C}_{13}\text{H}_8\text{O}_2$        |
| 26 Xanthopurpurin, see            | Dihydroxy anthraquinone  |                 |  |
| 27 Xylene, o                      | $(\text{CH}_3)_2:\text{C}_6\text{H}_4$   | 106.12          | $\text{C}_8\text{H}_{10}$                  |
| 28 —, m                           | " "  | 106.12          | "  |
| 29 —, p                           | " "  | 106.12          | "  |
| 30 — dihydro, 1:3:1:2             | $(\text{CH}_3)_2:\text{C}_6\text{H}_4(\text{H}_2)$   | 108.14          | $\text{C}_8\text{H}_{12}$                  |
| 31 —, 1:4:1:2                     | "  | 108.14          | "  |

| Density<br>H <sub>2</sub> O=1. | Solubility in |          |        | M.P.<br>°C. | B.P.<br>°C. |    |
|--------------------------------|---------------|----------|--------|-------------|-------------|----|
|                                | Water.        | Alcohol. | Ether. |             |             |    |
| 0.8185/11.2°                   | s.s.          | s.       |        | liq.        | 103.4       | 1  |
| 0.8041/15°                     | s.s.          | s.       | s.     | liq.        | 92—93       | 2  |
|                                | s             | s.       | s      | 126—128     | 230—232     | 3  |
| 0.9415/20°                     | 1: 27/16°     |          |        | - 18 to -20 | 185         | 4  |
| 0.9298/20°                     | 1: 24/20°     |          |        | - 51        | 173.7       | 5  |
|                                |               |          |        |             |             | 6  |
| 0.8765/20°                     | s.s.          | m.       | m.     | liq.        | 189—190     | 7  |
|                                |               |          |        |             | /757.4mm.   |    |
| 0.9007/0°                      | i.            | s.       |        | liq.        | 144.6       | 8  |
| 0.9097/0°                      |               |          |        |             | 127.3       | 9  |
| 0.9290/27°                     |               |          |        | liq.        | 205         | 10 |
| 0.7000/0°                      |               |          |        | liq.        | 55.5—56     | 11 |
|                                | h.s.          | s.       |        | 211         | subl.       | 12 |
|                                | h.s.          | s.       | s.     | 115         |             | 13 |
|                                | h.s.          | s.       | s.     | 81          | subl.       | 14 |
| 1.086/15°                      |               |          |        | 22.7        | 205—207     | 15 |
|                                |               |          |        |             | 56          | 16 |
| 1.5167/14°                     |               |          |        | liq.        | 16/750mm.   | 17 |
|                                |               |          |        | - 15        |             | 18 |
| 0.9125                         | s.s.          | m.       | m.     |             | 101         | 19 |
|                                | h.s.          | s.       |        |             |             | 20 |
|                                | v.s.s.        | s.       | s.     | 105         | 300—301     | 21 |
|                                | s.s.          | s.       | s.s.   | 38          |             | 22 |
| >H <sub>2</sub> O              | i.            |          |        | liq.        | d. 24       | 23 |
| 1.085/19°                      |               | s.       |        | liq.        | 200         | 24 |
|                                | h.s.s.        | h.s.     | s.s.   | 173—174     | 349—350     | 25 |
|                                |               |          |        |             | /730mm.     |    |
|                                |               |          |        |             |             | 26 |
| 0.8633/20°                     | i.            | v.s.     | v.s.   | 27.1        | 144.6       | 27 |
| 0.8642/20°                     | i.            | v.s.     | v.s.   | - 54.8      | 138.8—139.2 | 28 |
| 0.8612/20°                     | i.            | v.s.     | v.s.   | 13.2        | 137.8—138.1 | 29 |
|                                |               |          | s.     | liq.        | 131.5—133   | 30 |
|                                |               |          |        |             | /740mm.     |    |
|                                |               |          |        |             | 132.5—133.5 | 31 |

| Name.                                  | Formula.                 | Formula Weight. | Empirical Formula. |
|--|--------------------------|-----------------|--------------------|
| 1 Xylene, dihydro,<br>1:5:1:2          | " "                      | 108.14          | "                  |
| 2 —, 3:5:1:2                           | " "                      | 108.14          | "                  |
| 3 —, 3:6:1:2                           | " "                      | 108.14          | "                  |
| 4 —, 4:5:1:2                           | " "                      | 108.14          | "                  |
| 5 —, 2:5:1:4                           | " "                      | 108.14          | "                  |
| 6 —, tetrahydro, <i>m</i> ,<br>1:2:3:4 | $C_8H_{14}$              | 110.15          | $C_8H_{14}$        |
| 7 —sulphonic acid,<br>1:2:4            | $C_6H_3(CH_3)_2SO_3H$    | 186.18          | $C_8H_{10}O_3S$    |
| 8 Xylenol, 1:2:3                       | $C_6H_3(CH_3)_2OH$       | 122.12          | $C_8H_{10}O$       |
| 9 —, 1:2:4                             | " "                      | 122.12          | "                  |
| 10 —, 1:3:2                            | " "                      | 122.12          | "                  |
| 11 —, 1:3:4                            | " "                      | 122.12          | "                  |
| 12 —, 1:3:5                            | " "                      | 122.12          | "                  |
| 13 —, 1:4:2                            | " "                      | 122.12          | "                  |
| 14 Xylic acid, 1:3:4                   | $C_6H_3(CH_3)_2COOH$     | 150.13          | $C_9H_{10}O_2$     |
| 15 —, 1:2:4                            | " "                      | 150.13          | "                  |
| 16 —, 1:3:2                            | " "                      | 150.13          | "                  |
| 17 Xylidic acid, 1:2:5                 | $C_6H_3(CH_3)(COOH)_2$   | 180.11          | $C_9H_8O_4$        |
| 18 —, 1:2:4                            | " "                      | 180.11          | "                  |
| 19 —, 1:2:3                            | " "                      | 180.11          | "                  |
| 20 Xylidine, 1:2:3                     | $C_6H_3(CH_3)_2NH_2$     | 121.14          | $C_8H_{11}N$       |
| 21 —, 1:2:4                            | " "                      | 121.14          | "                  |
| 22 —, 1:3:4                            | " "                      | 121.14          | "                  |
| 23 —, 1:3:5                            | " "                      | 121.14          | "                  |
| 24 —, 1:4:2                            | $C_6H_3(CH_3)_2NH_2$     | 121.14          | $C_8H_{11}N$       |
| 25 Xyloquinone, 2:3                    | $(CH_3)_2C_6H_2O_2$      | 136.10          | $C_8H_8O_2$        |
| 26 —, 2:6                              | " "                      | 136.10          | "                  |
| 27 —, 2:5                              | " "                      | 136.10          | "                  |
| 28 Xylorcin, 1:3:4:6                   | $(CH_3)_2:C_6H_2:(OH)_2$ | 138.12          | $C_8H_{10}O_2$     |
| 29 Xylose, <i>d</i>                    | $C_5H_5(OH)_4CHO$        | 150.11          | $C_5H_{10}O_5$     |
| 30 Xylylene alcohol, <i>o</i>          | $CH_2OH.C_6H_4.CH_2OH$   | 138.12          | $C_8H_{10}O_2$     |
| 31 —, <i>m</i>                         | " "                      | 138.12          | "                  |
| 32 —, <i>p</i>                         | " "                      | 138.12          | "                  |
| 33 —cyanide, <i>o</i>                  | $CH_2CN.C_6H_4.CH_2CN$   | 156.13          | $C_{10}H_8N_2$     |
| 34 —, <i>m</i>                         | " "                      | 156.13          | "                  |
| 35 —, <i>p</i>                         | " "                      | 156.13          | "                  |

| Density<br>H <sub>2</sub> O=1.                                   | Solubility in |          |                     | M.P.<br>°C. | B.P.<br>°C.          |
|--|---------------|----------|---------------------|-------------|----------------------|
|  | Water.        | Alcohol. | Ether.              |             |                      |
| 0.814/0°   |               |          |                     |             | 129—130<br>/745mm. 1 |
|  |               |          |                     |             | 132—134 2            |
|  |               |          |                     |             | 135—138 3            |
|  |               |          |                     |             | 135.5—136.5 4        |
|  |               |          |                     |             | 133—134<br>/720mm 5  |
| 1.0362/0°<br>0.9709/81°<br>0.98/8°                               |               |          |                     |             | 124—125 6            |
|  |               |          |                     | d.          | 19 7                 |
|  | s.            | s.       |                     | 75          | 218 8                |
|  | s.            | s.       |                     | 85          | 225 9                |
|  | h.v.s.        | s.       |                     | 49          | 211—212 10           |
|  | v.s.s.        | m        | ma.                 | 26          | 211.5 11             |
|  | s.            | s.       |                     | 64          | 219.5 12             |
|  | s.            | s.       |                     | 74.5        | 211.5 13             |
|  | n.s.s.        | s.       | s.                  | 126—127     | 267/727mm. 14        |
|  | h.v.s.s.      | v.s      |                     | 165—166     | 15                   |
| 0.991/15°<br>1.0755/17.5°<br>0.9184/15°<br>0.9935/0°<br>0.98/15° | s.            |          |                     | 97—99       | 274.5 16             |
|  | h.s.s.        | s.       |                     | 280—283     | 17                   |
|  | s.s.          | h.v.s.   |                     | 320—330     | subl. 18             |
|  |               |          |                     | 144 d.      | 19                   |
|  |               |          |                     | liq.        | 223/739mm 20         |
|  | s.s.          |          | s. ligroin          | 49          | 226 21               |
|  |               |          |                     | liq.        | 212 22               |
|  |               |          |                     | liq.        | 220—221 23           |
|  |               |          |                     | 15.5        | 215/739mm 24         |
|  | s.s.          | s.       | p.                  | 55          | subl 25              |
| 1.161/18°  |               |          |                     | 72—73       | 26                   |
|  | h.s.s.        | s.s.     | s.                  | 61          | subl. 27             |
|  | s.            | s.       | s.                  | 124—125     | 276—279 28           |
|  | v.s           |          |                     | 141.5—143   | 29                   |
|  | s.            | s.       | s.                  | 64.2—64.8   | 30                   |
|  | v.s.          |          | s.                  | 46—47       | 31                   |
|  | v.s.          | v.s.     | v.s.                | 112—113     | 32                   |
|  |               | v.s.     | v.s.                | 59—60       | 33                   |
|  |               | s.       | s.CHCl <sub>3</sub> | 28—29       | 305—310/300mm 34     |
|  | h.s.s.        | h.s.     | s.CHCl <sub>3</sub> | 98          | 35                   |

| Name.                           | Formula.   | Formula Empirical<br>Weight. Formula.     |
|---------------------------------|--|---|
| 1 Xylylene dichloride, <i>o</i> | $\text{CH}_2\text{Cl}.\text{C}_6\text{H}_4.\text{CH}_2\text{Cl}$ | 175.02 $\text{C}_8\text{H}_8\text{Cl}_2$  |
| 2 —, <i>m</i>                   | " "  | 175.02 "                                  |
| 3 —, <i>p</i>                   | " "  | 175.02 "                                  |
| 4 Zinc diethyl                  | $\text{Zn}(\text{C}_2\text{H}_5)_2$                              | 123.47 $\text{C}_4\text{H}_{10}\text{Zn}$ |
| 5 -- dimethyl                   | $\text{Zn}(\text{OH}_3)_2$                                       | 95.43 $\text{C}_2\text{H}_6\text{Zn}$     |

| Density<br>H <sub>2</sub> O=1. | Solubility in |          |        | M.P.<br>°C. | B.P.<br>°C. |   |
|--------------------------------|---------------|----------|--------|-------------|-------------|---|
|                                | Water.        | Alcohol. | Ether. |             |             |   |
| 1.393/0°                       |               | v.s.     |        | 54.6—54.8   | 239—241     | 1 |
| 1.302/20°                      |               |          |        | 34.2        | 250—255     | 2 |
| 1.417/0°                       |               |          |        | 98—99       | 240—250     | 3 |
| 1.182/18°                      | d.            | d        | s.     | - 28        | 118         | 4 |
| 1.386/10.5°                    | d             |          |        | - 40        | 46          | 5 |

# QUALITATIVE ANALYSIS.

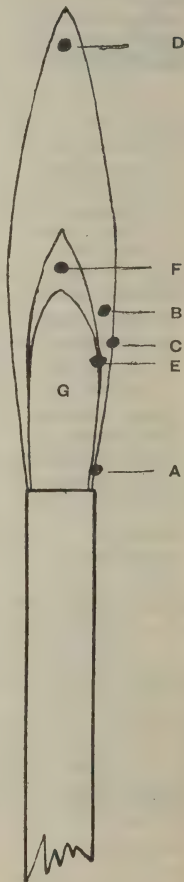
## Dry-way Tests.

The Bunsen flame has three main parts:

The inner portion (G), in which no combustion occurs, and in which the gas mixture contains about 60 per cent. of air, may be used for cooling beads from the reducing flame, to avoid oxidation; the mantle of the flame, including D, in which combustion of the mixed gases occurs; and the luminous portion, containing F, which is present only if there is an insufficient supply of air.

The six portions of the flame used are:

- A. *Base of flame.* Lowest temperature, for obtaining the flame coloration of the most volatile substance in a mixture of substances which colour the flame.
- B. *Zone of fusion.* Highest temperature (about  $1700^{\circ}\text{C.}$ ), for testing fusibility, volatility, etc.
- C. *Lower oxidising flame.* For further oxidation of oxides dissolved in beads.
- D. *Upper oxidising flame.* Best with draught holes completely open. For all oxidations unless they require a higher temperature.
- E. *Lower reducing flame.* As this contains unused air, it is not so energetic as F, and serves especially for reductions on charcoal and of beads of fused salts, a small flame being used for the latter.
- F. *Upper reducing flame.* Not visible when draught holes are quite open, but if made too large, soot is deposited. Contains carbon, but no free oxygen, and is therefore particularly suitable for reduction of metals to be identified as incrustations.





**TEST 1.**

A small amount of the substance is heated in a dry ignition tube.

The colour of the residue, and the nature of any gas evolved, is noted, and the behaviour of the residue and of the gas towards moistened litmus paper examined.

*(a) Character of Residue.*

Nitrates, carbonates, sulphates, etc., of many heavy metals, also certain metals, leave black or coloured residues of oxides on ignition.

Water vapour is formed, and condenses in the cooler portions of the test-tube: from moist substances, and in larger amounts at comparatively low temperatures from salts containing water of crystallisation, and at higher temperatures from the dehydration of hydroxides and the decomposition of certain ammonium salts. The behaviour of the condensed water towards litmus paper is examined:

*Alkaline* reaction indicates an ammonium salt.

*Acid* reaction indicates presence of a volatile acid, such as one of the halogen acids, sulphurous, sulphuric, nitric, or acetic acid.

Many *Organic compounds* carbonise on heating, giving a black residue.

*Metallic chlorides* (silver chloride, sodium chloride, etc.) are characterised by the comparative readiness with which they can be fused.

| <i>Substance</i> | <i>Original colour</i> | <i>Colour on heating</i>   |
|------------------|------------------------|--|
| Lead monoxide    | Yellowish brown        | *Reddish brown (fuses into test-tube, forming bright yellow glass)               |
| Mercuric oxide   | Scarlet or yellow      | *Black (on heating to a higher temperature gives oxygen and globules of mercury) |
| Bismuth oxide    | Greenish yellow        | *Orange to reddish brown   |
| Red lead         | Red                    | *Black (yields oxygen at a higher temperature)                                   |
| Ferric oxide     | Red                    | *Black   |
| Zinc oxide       | White                  | *Yellow  |
| Stannic oxide    | White                  | *Pale yellowish brown  |
| Cadmium oxide    | Brown                  | *Dark brown  |
| Cuprous oxide    | Reddish brown          | Black  |
| Tungstic oxide   | Yellowish green        | *Dark orange   |
| Molybdic oxide   | Pale yellowish green   | *Orange  |
| Titanic oxide    | White                  | Yellow (at higher temperatures, brown)   |

\* Indicates temporary change only.

(b) *Evolution of Gas*, or other volatile decomposition product.

*Product and its detection*

*Indicates*

Oxygen

Certain metallic oxides which decompose on heating into the metal and oxygen (*e.g.*, mercuric oxide, silver oxide), dioxides (*e.g.*, of manganese and lead) or peroxides (*e.g.*, of barium, calcium, and sodium), chlorates, bromates, perchlorates, percarbonates, persulphates, perborates, permanganates, and some nitrates and chromates.  
Alkali formates.

Hydrogen.

Platinic, auric, and certain other chlorides.

Chlorine (by greenish colour, bleaches litmus paper, and by smell).

Hydrochloric acid (forms white fumes with ammonia).

Magnesium, barium, and certain other chlorides.

Bromine (brown fumes, characteristic odour).

Bromides in presence of oxidising substances.

Iodine (violet vapours, also given after mixing with ferrous sulphate).

Iodides, in presence of oxidising substances, or iodates.

Hydrofluoric acid (test-tube etched).

Certain fluorides in presence of water.

Ammonia (by smell and alkaline reaction to litmus paper).

Ammonium salts (other than nitrate and nitrite), and, under certain conditions, cyanides and cyanates.

(*Note*.—Ammonium dichromate and chromate deflagrate vigorously on heating, evolving nitrogen and ammonia, and leaving a green residue of chromic oxide. Ammonium phosphate and borate leave glassy residues.)

Nitrogen (extinguishes burning splint).

Nitrites in presence of ammonium salts and moisture.

Nitrous oxide.

Ammonium nitrate.

Oxides of nitrogen (by reddish colour).

Nitrates of the heavy metals.

Carbon dioxide (by baryta water test), sometimes mixed with carbon monoxide.

Carbonates; carbon in presence of reducible oxides, or nitrates; cyanates.

Carbon monoxide (burns with blue flame), often mixed with carbon dioxide or hydrogen.

Oxalates.

Carbon disulphide (smell).

Thiocyanates of heavy metals.

Cyanogen (smell and carmine flame).

Cyanides of certain heavy metals; cyanates; thiocyanates.

Methane (luminous flame) accompanied by odour of acetone.

Acetates in presence of alkalis.

*Product and its detection**Indicates*

|   |   |
|---|---|
| Sulphur dioxide (smell and reducing action).                | Acid sulphites; sulphates of certain heavy metals; some thiosulphates; sulphur; sulphides; thiocyanates, etc., in presence of oxidising substances. |
| Sulphuric acid fumes.                                       | Bisulphates.  |
| Hydrogen sulphide (smell, and blackens lead acetate paper). | Sulphides, and thiosulphates in presence of water; hydro-sulphites.   |
| Hydrogen phosphide (by odour).                              | Phosphites, and hypophosphites.   |

(c) *Volatile product forms a sublimate.*

Sublimate collected and heated with a mixture of two parts of powdered charcoal and two parts of fusion mixture.

| <i>Substance</i>                          | <i>Nature of Sublimate</i>                             | <i>On reheating as above</i>                                    |
|---|--|---|
| Ammonium salt                             | White  | Smell of ammonia; no sublimate                                  |
| Mercuric chloride                         | White (substance melts readily)                        | Metallic mirror and globules of mercury                         |
| Mercurous chloride or bromide             | White (substance does not melt)                        |   |
| Mercuric nitrate, oxide, or cyanide       | Metallic globules                                      |   |
| Mercuric iodide                           | Yellow, red on rubbing                                 |   |
| Mercuric sulphide                         | Black, and metallic globules                           | Metallic mirror instantly dissolved by hypochlorite solution    |
| Arsenious oxide (and hence arsenic oxide) | White, crystalline, deposited at distance from flame   |   |
| Arsenious sulphide                        | Reddish yellow   |   |
| Antimony oxide                            | Glittering white needles, deposited near flame         | Metallic mirror, very slowly dissolved by hypochlorite solution |
| Stibnite (antimony sulphide)              | White  |   |
| Lead chloride                             | White (only formed at high temperature), fuses readily |   |
| Sulphur, polysulphide, thiosulphate       | Yellow, deep red drops when hot                        |   |
| Iodine, certain iodides and iodates       | Black, crystalline                                     |   |
| Oxalic acid                               | White crystalline, with white fumes                    |   |

**TEST 2.**

**Substance is heated with potassium bisulphate.**

In addition to results given by Test I (δ) :

|  |   |
|--|---|
| Oxygen (and red or green liquid).                      | Chromates.  |
| Acid fumes (dense white fumes with ammonia).           | Halides.  |
| Chlorine dioxide (similar to chlorine, but explosive). | Chlorates.  |
| Hydrofluoric acid (test-tube etched)                   | Fluorides, hydrofluosilicates.                              |
| Oxides of nitrogen.                                    | Nitrites; nitrates (best in presence of copper).            |
| Carbon monoxide (burns with blue flame).               | Formates; oxalates; cyanides; ferrocyanides; ferricyanides. |
| Acetic acid (characteristic smell).                    | Acetates.   |

**TEST 3.**

**Substance is moistened with pure, concentrated hydrochloric acid and heated on a platinum wire in the non-luminous Bunsen flame.**

| <i>Flame Coloration.</i> | <i>Indicates</i>           |
|--------------------------|----------------------------|
| Lavender violet.         | Potassium.                 |
| Vivid bluish white.      | Lead, arsenic, antimony.   |
| Blue (afterwards green). | Copper.                    |
| Green.                   | Barium.                    |
| Faint yellowish green.   | Molybdenum.                |
| Yellowish green.         | Boron, manganese chloride. |
| Golden yellow.           | Sodium.                    |
| Carmine red.             | Lithium.                   |
| Brick red.               | Calcium.                   |
| Crimson.                 | Strontium.                 |

In the case of substances such as barium sulphate, the flame coloration is best obtained by first heating the substance in the reducing flame and then moistening with hydrochloric acid. The boron flame is best given in presence of sulphuric acid, and, in presence of silicates, after admixture with calcium fluoride and potassium bisulphate.

Care should be taken to distinguish the above flame colorations from scintillations, such as are obtained with bismuth, zinc, etc., salts.

In presence of sodium, the potassium flame is masked, but is visible as a reddish violet through a blue cobalt (or better, a didymium) glass, which cuts out the sodium flame. This precaution does not, however, prevent the masking of the potassium flame in presence of strontium, lithium, and calcium. The strontium and calcium flames are sometimes masked by the presence of barium, and that of lithium by the sodium flame.

Traces of sodium are present in most compounds, and in testing for sodium the flame coloration should persist and should not be appreciably increased in intensity by mixing about 1 per cent. of sodium chloride with the original solid.

**TEST 4.**

A small fragment of the substance is heated with a colourless borax bead ( $1-1\frac{1}{2}$  mm. diam.) on a platinum wire.

| Oxides of  | Oxidising flame    |                               | Reducing flame  |                       |
|------------|--------------------|-------------------------------|-----------------|-----------------------|
|            | Hot                | Cold                          | Hot             | Cold                  |
| Copper     | Green              | Bluish green                  | Colourless      | Brown to red (cloudy) |
| Iron       | Yellowish brown    | Yellow or colourless          | Bottle green    | Bottle green          |
| Chromium   | Yellow or dark red | Yellowish green               | Green           | Emerald green         |
| Manganese  | Amethyst           | Reddish violet                | Colourless      | Colourless            |
| Cobalt     | Blue               | Blue                          | Blue            | Blue                  |
| Nickel     | Violet             | Reddish brown                 | Grey (cloudy)   | Grey (cloudy)         |
| Molybdenum | Yellow to brown    | Yellowish green to colourless | Dark brown      | Green                 |
| Titanium   | Colourless         | Colourless                    | Yellow to brown | Violet                |
| Uranium    | Yellow             | Yellowish green               | Green           | Bottle green          |
| Vanadium   | Brown to yellow    | Greenish yellow               | Brown           | Bottle green          |

To cool beads from the reducing flame, they are held in the cold gas-mixture just above the Bunsen tube. Reduced beads of *uranium*, etc., are best obtained by introducing a fragment of stannous chloride into the bead. In the presence of iron (e.g., in rutile), *titanium* gives a brownish-red bead.

The colours of the borax beads obtained with metallic sulphides and arsenides frequently differ from those given by the other salts and the oxides, e.g., manganese sulphide gives a brown bead. If sulphide or arsenide is suspected, this difficulty may be overcome by fusing with a fragment of sodium peroxide.

**TEST 5.**

A fragment of the substance is introduced into a bead made from microcosmic salt.

In presence of *silica* or *silicates*, undissolved particles are noticed in the bead.

This metaphosphate bead gives similar colorations to the borax bead. The results given by *molybdenum* and *titanium* are more characteristic in the case of the metaphosphate bead. In the reducing flame *tungsten* gives a blue metaphosphate bead, which becomes blood-red on the introduction of ferrous sulphate.

**TEST 6.**

(a) A fragment of the solid is heated in an opaque bead of fusion mixture on a platinum wire.

|                |  |
|----------------|--|
| Effervescence. | Silica, silicate; stannic, titanio, tungstic or molybdic oxides. |
| Yellow.        | Chromate, dichromate.  |

(b) If (a) gives a white bead, it is re-heated with a fragment of sodium peroxide, or of potassium nitrate on platinum foil.

|         |                     |
|---------|---------------------|
| Yellow. | Chromium, vanadium. |
| Green.  | Manganese.          |

**TEST 7.**

(a) The substance is heated in a clean cavity in a charcoal block in the oxidising flame.

In addition to results of Test 1 (a) :

|   |   |
|---|---|
| Deflagration.                                   | Nitrate, chlorate, etc  |
| Intumescence.                                   | Certain salts containing water of crystallisation, <i>e.g.</i> borax. |
| Infusible light powder.                         | Alumina.  |
| Infusible white mass, incandescent whilst hot : |   |
| Alkaline residue.                               | Barium, strontium, calcium, or magnesium oxide.                       |
| Neutral residue.                                | Zinc oxide.   |
| Incrustation.                                   | See Test 8.   |

(b) The mass from (a) is heated in the oxidising flame after moistening with two drops of cobalt nitrate solution.

A light powder (such as alumina) may be retained on the charcoal by first fusing with a small amount of fusion mixture.

|                                  |   |
|----------------------------------|---|
| Deep blue, fusible mass.         | Phosphates, arsenates of sodium, potassium, calcium, strontium, and barium. |
| Blue.                            | Silica, silicate, borate, tungstate.  |
| Light blue, infusible mass.      | Aluminium.  |
| Bluish green.                    | Tin.  |
| Green                            | Zinc.   |
| Yellowish green, infusible mass. | Titanium.   |
| Dull green.                      | Antimony.   |
| Pink (indistinct).               | Magnesium.  |
| Brown.                           | Barium.   |

**TEST 8.**

(a) In case substance has been found to deflagrate, it is first heated alone on charcoal.

Otherwise it is mixed directly with twice the amount of fusion mixture, and heated on charcoal in the reducing flame of the blow-pipe.



The product is crushed in water in a small mortar, and the washed particles tested for malleability, and with a magnetised penknife blade for magnetic properties. Colours of incrustation when hot and cold are to be compared with Test 1 (a).

|  |                       |
|--|-----------------------|
| Brilliant white malleable bead,  | Silver.               |
| dark red incrustation.   |                       |
| Malleable white bead (marks paper), yellow incrustation.                                 | Lead.                 |
| Brittle white bead, bluish white incrustation.   | Antimony              |
| Brittle white bead, yellow incrustation.   | Bismuth.              |
| Malleable white bead (slight yellow incrustation).                                       | Tin.                  |
| Malleable red bead.  | Copper.               |
| Yellow bead.   | Gold.                 |
| White incrustation. No bead.   | Zinc.                 |
| Black incrustation, brown at edges. Yellow on fusing with anhydrous sodium thiosulphate. | Cadmium.              |
| No bead.   |                       |
| Deep blue incrustation.  | Molybdenum.           |
| Volatile white incrustation, garlic odour.   | Arsenic.              |
| Grey magnetic powder   | Iron, cobalt, nickel. |

The powder is separated by a magnetised blade, dissolved in dilute nitric acid in an evaporating dish, and solution evaporated just to dryness over a small flame.

|                |         |
|----------------|---------|
| Brown residue. | Iron.   |
| Pink residue.  | Cobalt. |
| Green residue. | Nickel. |

(b) If (a) fails to give a bead, a fragment of potassium cyanide is added and the mass re-heated, when the tin and copper beads, for example, will be more easily obtained.

(N.B.—If found to be present by Test 2, nitrates must be destroyed by a preliminary heating, or the mixture may be explosive.)

*Note.*—The bead obtained may be an alloy, and the following tests may be used to confirm the test. The metallic bead is divided into two pieces, and tested on a watch-glass as follows :

I. One half is warmed with dilute nitric acid (1 : 4).

|                          |                                |
|--------------------------|--------------------------------|
| White residue.           | Antimony, tin.                 |
| Soluble with difficulty. | Arsenic, bismuth, mercury.     |
| Readily soluble.         | Lead, cadmium, silver, copper. |

(i) Solution is decanted from residue and separate portions spotted on watch-glasses with—

|                           |  |
|---------------------------|--|
| Dilute hydrochloric acid. | White precipitate in presence of silver or lead, and, at suitable concentrations, with bismuth.  |
| Dilute sulphuric acid.    | White precipitate in presence of lead.   |
| Ammonia.                  | Blue solution in presence of copper.   |
| Ammonium sulphide.        | Yellow precipitate in presence of arsenic; brighter yellow precipitate in presence of cadmium; black precipitate in presence of silver, lead, bismuth, or mercury. |

(ii) Residue is treated with ammonium sulphide.

|         |           |
|---------|-----------|
| Brown.  | Tin.      |
| Orange. | Antimony. |

II. If soluble, the remainder of bead is dissolved in hydrochloric acid (1:1), and mercuric chloride solution added.

White or grey precipitate. Tin.

### TEST 9.

The substance is mixed with slaked lime, and heated in an ignition tube.

Evolution of ammonia Ammonium salt.

(smell and alkaline reaction).

Evolution of methane Acetate.

(also smell of acetone).

### TEST 10.

A lump of copper oxide held in a platinum wire is heated in the non-luminous Bunsen flame, some of the substance placed on the copper oxide and then heated.

Blue flame (afterwards green). Chloride, bromide, or iodide.

### TEST 11.

(a) Substance is placed on a piece of silver foil or a silver coin and moistened with a drop of water.

Black or brown stain on silver. Sulphide.

(b) Substance is mixed with starch and fusion mixture and heated in an ignition tube. The mass is broken on a piece of silver foil or a silver coin and moistened with water

Black or brown stain on silver. Sulphur in some form.

The presence of mercury interferes with this test.



**TEST 12.**

The residue obtained by igniting some of the substance on a crucible lid is powdered, a piece of magnesium ribbon added, and the mixture heated in a test-tube. The test-tube is broken in an evaporating dish, and moistened with water.

Evolution of spontaneously inflammable gas (smell of decayed fish). Phosphate, or phosphorus in some other form.

Evolution of spontaneously inflammable gas (green flame). Borate, or boron in some other form.

## SOLUTION ANALYSIS.

The main points of interest in the theoretical considerations governing the use and value of the tests employed in solution analysis are: (1) the Theory of Ionic Dissociation, and its consideration in conjunction with the Law of Mass Action, and (2) the formation of Complex Salts.

According to the theory of ionic dissociation, the methods of solution analysis may be regarded as depending almost entirely on the chemistry of the *ions* and not of the *elements*. The characteristic reactions of ions containing the elements are used for the identification of the elements, and the condition in which they are present (e.g., arsenic as chloride, or arsenate, etc.) In other words: *the properties of a dilute solution of a salt are, in general, the sum of the properties of its ions.*

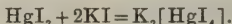
The process of *neutralisation* is essentially an ionic reaction. The neutralisation depends on the combination of hydrogen ions (the presence of which is known as acidity) with hydroxyl ions (the presence of which is known as alkalinity) to form the practically non-ionised water.

A detailed account of the theory of ionic dissociation, the reasons for its adoption and its advantages as a working hypothesis, will be found in most text-books on theoretical chemistry.

### *Formation of Complex Ions.*

On adding a solution of potassium iodide to a solution of mercuric chloride, the precipitate of mercuric iodide is found to be soluble in an excess of potassium iodide. The addition of caustic soda to this solution does not give a precipitate, whereas the addition of caustic soda to the mercuric chloride solution would give a precipitate. The reactions of salts in

solution have already been stated to be the sum of the reactions of their ions, and hence the mercuric ion must be absent from the former solution. This is considered to be due to the presence in the solution of a *complex ion*,  $[\text{HgI}_4]$ , which contains the mercury in a form in which it does not give the reactions of the mercuric ion, thus :



On ionisation, this compound will give  $\text{K}'$  and  $[\text{HgI}_4]''$  ions, but no  $\text{Hg}''$  ions.

Similar considerations apply to many other halides, and to the cyanides. For example, a method frequently used for detecting cadmium in presence of copper (Group II separation) is to add potassium cyanide to the blue, ammoniacal solution until it has become decolorised, and then to pass in hydrogen sulphide to precipitate any cadmium present. [A disadvantage of this method is that, in presence of much copper, a red or orange precipitate of dithio-oxamide is obtained, and this may be mistaken for cadmium sulphide.] This method depends upon the solution of cupric cyanide in an excess of potassium cyanide to form a compound in which the copper is present in a colourless complex ion, from which it is not precipitated by hydrogen sulphide; hence the disappearance of the characteristic blue colour of the cupric ion on addition of potassium cyanide.

In ammoniacal solution, copper is present in an intense blue complex ion  $[\text{Cu}(\text{NH}_3)_4]$ .

The so-called "platinic chloride," used in testing for potassium, is actually chlorplatinic acid  $\text{H}_2[\text{PtCl}_6]$ , in which the platinum forms part of a complex anion. The addition of the true platinic chloride ( $\text{PtCl}_4$ ) to a solution of potassium chloride gives a precipitate only after standing for a considerable time, on account of the extremely slow formation of the potassium chlorplatinate,  $\text{K}_2[\text{PtCl}_6]$ , under these conditions. Similarly "auric chloride" is actually the compound chlorauric acid,  $\text{H}[\text{AuCl}_4]$ , and the colourless solution of cuprous chloride in hydrochloric acid contains a complex compound, probably  $\text{H}_2[\text{CuCl}_3]$ .

The *double salts* should be differentiated carefully from the *complex salts*. Whereas the latter contain complex ions in solution, solutions of double salts, such as the alums, give the same ionic reactions as the single salts. In this connection it is to be noted, however, that certain complex salts undergo a secondary dissociation, *e.g.*, solutions of ferri-oxalates contain ferric and oxalate ions in addition to  $[\text{Fe}(\text{C}_2\text{O}_4)_3]$  ions.

## SOLUTION OF A SOLID SUBSTANCE.

The behaviour of the substance on warming with the following solvents should be examined :

### (1) *Water.*

| <i>Evolution of</i> | <i>Indicates</i>  |
|---------------------|---|
| Oxygen.             | Peroxides of the alkali or alkaline earth metals.                 |
| Methane.            | Aluminium and other carbides.                                     |
| Acetylene.          | Calcium and other carbides.                                       |
| Ammonia.            | Nitrides, metallic amides, cyanamides.                            |
| Hydrochloric acid.  | Chlorides of certain non-metals.                                  |
| Carbon dioxide.     | Bicarbonate, or carbonate in presence of an acid or an acid salt. |
| Hydrogen phosphide  | Phosphides of the alkali or alkaline earth metals.                |
| Hydrogen sulphide.  | Sulphides of magnesium, aluminium, etc.                           |

### (2) *Dilute hydrochloric acid.*

| <i>Evolution of</i>                          | <i>Indicates</i>                     |
|--|--------------------------------------|
| Hydrogen.                                    | Presence of a metal.                 |
| Oxygen.                                      | Peroxide.                            |
| Chlorine.                                    | Presence of an oxidising agent.      |
| Oxides of nitrogen.                          | Nitrite.                             |
| Carbon dioxide.                              | Carbonate, percarbonate, cyanate.    |
| Methane, acetylene, etc.                     | Carbide.                             |
| Acetic acid.                                 | Acetate.                             |
| Sulphur dioxide.                             | Sulphite.                            |
| Sulphur dioxide and liberation of sulphur.   | Thiosulphate.                        |
| Hydrogen sulphide.                           | Sulphide, hydrosulphite.             |
| Hydrogen sulphide and liberation of sulphur. | Polysulphide.                        |
| Hydrogen cyanide.                            | Cyanide, ferrocyanide, ferricyanide. |

(3) *Concentrated hydrochloric acid.* As certain metallic chlorides are volatile with hydrochloric acid, such a solution may be warmed, but should not be boiled.

(4) *Dilute nitric acid.* In addition to the behaviour observed in (2) :

|                             |                    |
|-----------------------------|--------------------|
| Evolution of nitrous fumes. | Presence of metal. |
|-----------------------------|--------------------|

(5) *Concentrated nitric acid.* Mercurous chloride dissolves as mercuric nitrate, and hence the state of the mercury must be ascertained by testing in the original solid (*e.g.*, blackening by ammonia indicates mercurous chloride).

Solutions in nitric acid should be evaporated almost to dryness before proceeding with the analysis. It is to be remembered that sulphides, etc., have probably been oxidised by the treatment with nitric acid.

(6) *Concentrated sulphuric acid* decomposes complex cyanides.

(7) *Aqua regia*. (One vol. of concentrated nitric acid to four vols. of concentrated hydrochloric acid). This should only be used if all the above solvents have failed.

All solutions in strong acids must be diluted with five or six times their volume of water before proceeding to the group tests.

White precipitate on dilution, Antimony or bismuth (the former soluble in hydrochloric acid. only is soluble in tartaric acid).

In case it is not found possible to dissolve the whole of the substance, a portion may have been dissolved by one of the above solvents (as found by carefully evaporating some of the filtrate to dryness at the lowest possible temperature). The solution obtained is used for the group tests, and the residue examined by the special tests for insoluble substances.

## EXAMINATION OF A SOLUTION.

### *General tests.*

(a) Unless the solution has been made by dissolving a substance in an acid as above, its smell should be noted, and it should be tested with litmus paper.

### *Alkaline solution.*

Presence of an alkali, basic salt, hydrolysed salt of a strong base with a weak acid (normal alkali carbonate, alkali borate, cyanide, sulphide, silicate, hypochlorite, commercial alkali nitrate, trimetallic phosphate, stannate, antimonate, zincate, molybdate, or tungstate).

### *Acid solution.*

Presence of an acid, acid salt (bisulphate, bicarbonate, acid phosphate, dichromate) or hydrolysed salt of a strong acid with a weak base (cupric, ferric, etc. salts).

(b) It is useful, though not conclusive, to note the colour of the solution; the following is a list of the commoner colour ions :

| Cations |   | Anions |                          |
|---------|---|--------|--------------------------|
| Lilac   | Titanous                                  | Purple | Permanganate             |
| Blue    | Cupric, tungstous, molybdenous            | Green  | Manganate, ferri-cyanide |
| Green   | Cupric, cuprous, nickel, ferrous, chromic | Orange | Dichromate               |
| Yellow  | Ferric, uranium                           | Yellow | Chromate, ferrocyanide   |
| Pink    | Cobalt, manganese                         |        |                          |

In addition, bromine solution is orange, and a solution of iodine in an iodide is brown.

(c) A small portion is evaporated to dryness and examined by dry-way tests. In case no residue is obtained, and solution is acid, it is neutralised with sodium carbonate and tested for acids.

(d) *Special tests for Hydrogen peroxide.*

(1) In case solution is slightly alkaline, cobalt nitrate solution is added. Black precipitate in absence of hypochlorite and sulphide (which could not co-exist with hydrogen peroxide, as they would be reduced to chloride and oxidised to sulphate respectively) indicates hydrogen peroxide.

(2) Solutions of gold are reduced to the metal, with liberation of oxygen, at the ordinary temperature by alkaline hydrogen peroxide.

(3) In the case of an acid solution, titanium sulphate is added. A yellow coloration due to the formation of per-titanic acid indicates the presence of hydrogen peroxide, in absence of chlorate.

(4) The dichromate test is also available for the detection of hydrogen peroxide in acid solution, provided that a "blank" is carried out. The solution is acidified with sulphuric acid and potassium dichromate solution added. The liquid is shaken with ether, when a blue ethereal layer, due to perchromic acid, indicates the presence of hydrogen peroxide.

*Tests for Ozone.* Ozone does not (1) give a yellow coloration with titanium sulphate, or (2) precipitate gold from solutions of its salts, but (1) liberates iodine *immediately* from dilute neutral potassium iodide solution, (2) liberates bromine immediately from an acidulated solution of sodium bromide, and (3) immediately turns silver foil heated to 250° steel blue (this reaction does not occur in the cold unless the silver foil has been treated with nitric acid, or has been cleaned

with emery paper, the iron oxide in which appears to act as a catalyst). These latter reactions are not given by hydrogen peroxide.

(e) *Detection of free Alkali.*

After destroying hydrogen peroxide by boiling, the presence of free alkali, possibly formed by the hydrolysis of an alkali peroxide, in an alkaline solution may be detected in presence of an alkali carbonate by adding an excess of barium chloride and filtering to remove the barium carbonate precipitated. Alkaline filtrate indicates presence of free alkali.

## I. Acid Radicals (Anions).

### TEST 1.

The substance is warmed with dilute sulphuric acid :

| <i>Evolution of</i>                          | <i>Indicates</i>   |
|--|--|
| Hydrogen.                                    | A metal.   |
| Oxygen.                                      | Peroxide.  |
| Chlorine.                                    | Hypochlorite, or chloride in presence of an oxidising agent. |
| Oxides of nitrogen.                          | Nitrite.   |
| Carbon dioxide.                              | Carbonate, percarbonate, cyanate.                            |
| Methane, acetylene, etc.                     | Carbide.   |
| Acetic acid.                                 | Acetate.   |
| Sulphur dioxide.                             | Sulphite.  |
| Sulphur dioxide and liberation of sulphur.   | Thiosulphate, thiocyanate.                                   |
| Hydrogen sulphide.                           | Sulphide.  |
| Hydrogen sulphide and liberation of sulphur. | Polysulphide, hydrosulphite.                                 |
| Hydrogen cyanide.                            | Cyanide, ferrocyanide, ferri-cyanide.                        |

### TEST 2.

The substance is heated with concentrated hydrochloric acid :

| <i>Evolution of</i>                   | <i>Indicates</i>   |
|---------------------------------------|--|
| Chlorine.                             | Presence of an oxidising agent, e.g., dioxide, chlorate, nitrate, persulphate, chromate, dichromate, permanganate. |
| Carbon dioxide and hydrogen sulphide. | Thiocyanate.   |



**TEST 3.**

A small amount of the substance is warmed very cautiously with a few drops of concentrated sulphuric acid. In addition to results in Test 1 :

| <i>Evolution of</i>   | <i>Indicates</i>  |
|---|---|
| Oxygen (frequently mixed with ozone).                               | oxide, permanganate, dichromate, chromate, persulphate. |
| Hydrochloric acid.  | Chloride.   |
| Chlorine.   | Chloride in presence of an oxidising agent.             |
| Chlorine dioxide (explosive).                                       | Chlorate.   |
| Chromyl chloride (colours non-luminous Bunsen flame white).         | Chloride in presence of a chromate.                     |
| Bromine.  | Bromide or bromate.                                     |
| Iodine.   | Iodide or iodate.                                       |
| Silicon fluoride.   | Fluoride, hydrofluosilicates.                           |
| Oxides of nitrogen.   | Nitrate.  |
| Sulphur dioxide.  | Metal, sulphide, carbon in some form.                   |
| Sulphur dioxide and liberation of sulphur.                          | Thiosulphate, thiocyanate.                              |
| Sulphur dioxide and hydrogen sulphide, in addition to iodine.       | Iodide.   |
| Carbon monoxide.  | Cyanide, ferrocyanide.                                  |
| Carbon dioxide and monoxide (without blackening).                   | Ferricyanide, oxalate.                                  |
| Carbon dioxide and monoxide, and sulphur dioxide (with blackening). | Tartrate.   |

**TEST 4.**

The substance is heated with manganese dioxide and dilute sulphuric acid. In addition to results in Test 3 :

|           |           |
|-----------|-----------|
| Chlorine. | Chloride. |
| Bromine.  | Bromide.  |
| Iodine.   | Iodide.   |

**TEST 5.**

Substance or solution is boiled with an excess of sodium carbonate\* solution for five minutes, and filtered if necessary. The clear filtrate is divided into three portions, and treated as follows :

- (1) One portion is neutralised by adding dilute nitric acid†

\* Chloride and sulphate are frequently present in traces in sodium carbonate, and hence a "blank" should be carried out, unless the precipitates obtained (with silver nitrate and barium chloride respectively) are very definite.

† On acidifying with nitric acid, any sulphite, sulphide, etc., in the solution may be decomposed. A precipitate may be obtained in presence of certain sulphur acids, silicates, tungstates, molybdates, zincates, stannites, stannates, etc. The ppt. is examined by the dry-way tests, and the filtrate tested for acid radicals.

slowly until no more effervescence occurs on further addition, then ammonium carbonate added again until no further effervescence occurs, and the liquid boiled for several minutes to destroy the excess. The neutral solution is treated with :

*Silver nitrate solution.* After filtering, the behaviour of portions of the precipitate towards hot water, dilute nitric acid, and ammonia is examined. In case the nitric acid appears to dissolve any of the precipitate, the liquid is filtered, and ammonia added carefully to the filtrate to reprecipitate the silver salt, which may probably be identified by the colour of the ring produced.

*White precipitate :*

Soluble in hot water.

Sulphate, nitrite, acetate,  
benzoate, salicylate.  
Silicate

Decomposed by acetic acid.

Insoluble in dilute nitric acid :

Soluble on heating. Solution in ammonia (1 : 20) gives yellow precipitate on addition of sulphur dioxide.

Bromate, iodate.

Curdy precipitate, soluble in ammonia.

Chloride, hypochlorite,  
cyanide, thiocyanate.  
Ferrocyanide.

Insoluble in ammonia, soluble in potassium cyanide, becomes orange and soluble in ammonia on boiling with concentrated nitric acid.

Soluble with difficulty in nitric acid.

Selenite.

Soluble in nitric acid and in ammonia :

Curdy precipitate.

Cyanate, pyrophosphate,  
molybdate, oxalate.  
Tartrate.

Curdy precipitate, solution in ammonia deposits silver on warming.

Amorphous precipitate.

Metaphosphate.  
Borate.

Amorphous precipitate, becomes brown on warming.

Crystalline precipitate, becomes black on warming.

Sulphite, thiosulphate,  
formate, citrate.

*Pale yellow precipitate :*

Insoluble in dilute nitric acid and in very dilute ammonia (1 : 20).

Bromide.

*Yellow precipitate :*

Insoluble in dilute nitric acid and in ammonia.

Iodide.

Soluble in nitric acid and in ammonia :

Insoluble in acetic acid.

Phosphate.  
Arsenite.

Soluble with difficulty in acetic acid; solution in ammonia deposits silver on warming.

Curdy, brownish precipitate.

Vanadate.



*Orange precipitate :*

Insoluble in dilute nitric acid, soluble in ammonia and in potassium cyanide.

Ferricyanide

*Chocolate brown precipitate :*

Soluble in nitric acid and in ammonia, insoluble in acetic acid.

Arsenate.

*Reddish brown precipitate :*

Soluble in nitric acid and in ammonia, insoluble in acetic acid.

Chromate.

*Black precipitate :*

Insoluble in cold, dilute nitric acid, dissolves on warming.

Sulphide, hydrosulphite.

Soluble in cold, dilute nitric acid.

Phosphite, hypophosphite.

(2) Another portion is neutralised as in (1), using hydrochloric acid in place of nitric acid, and the neutral solution divided into three portions. To these are added :

*(a) Calcium chloride solution.*

White crystalline precipitate, soluble in concentrated hydrochloric acid

Sulphate or sulphite (in considerable amount).

White precipitate, soluble in acids.

Phosphite.

White precipitate, decomposed by acetic acid.

Silicate.

White precipitate, soluble in excess of pyrophosphate.

Pyrophosphate

White amorphous precipitate, soluble in acetic acid and in ammonium chloride.

Borate.

White amorphous precipitate, (gelatinous in presence of ammonia), soluble in acetic acid.

Phosphate, arsenate, arsenite.

White amorphous precipitate, soluble in hydrochloric acid (reprecipitated by ammonia), insoluble in acetic acid.

Oxalate.

White gelatinous precipitate, soluble in acetic acid (until the precipitate has become crystalline). Soluble in caustic potash, precipitated on warming, redissolves on cooling.

Tartrate

White gelatinous precipitate, soluble with difficulty in dilute hydrochloric acid, insoluble in acetic acid, soluble in ammonium chloride.

Fluoride.

White precipitate, less soluble in hot water than in cold, insoluble in caustic potash, soluble in ammonium chloride.

Citrate.

White precipitate on warming.

Ferrocyanide

White precipitate on addition of alcohol.

Malate

(b) *Barium chloride solution.*

|   |   |
|---|---|
| White precipitate, soluble in hydrochloric acid.  | Sulphite, selenite, phosphate, arsenate, arsenite, borate, bromate, iodate, periodate, pyrophosphate, molybdate, vanadate, oxalate, tartrate. |
| (If sulphite is present, addition of bromine water to solution of precipitate in hydrochloric acid gives precipitate of barium sulphate.) |   |
| White precipitate, soluble in excess of metaphosphate and in hydrochloric acid.   | Metaphosphate.  |
| White precipitate decomposed by acetic acid.  | Silicate.   |
| White precipitate, soluble in acetic acid.  | Phosphite.  |
| White, crystalline precipitate almost insoluble in dilute hydrochloric acid.  | Hydrofluosilicate.  |
| White, voluminous precipitate, soluble with difficulty in hydrochloric acid.  | Fluoride.   |
| White precipitate, insoluble in concentrated hydrochloric acid.   | Sulphate.   |
| White precipitate, insoluble in nitric acid, soluble in hydrochloric acid.  | Selenate.   |
| White precipitate on boiling.   | Persulphate, ferrocyanide   |
| White precipitate in concentrated solution.   | Thiosulphate.   |
| Yellow precipitate, soluble in dilute hydrochloric and nitric acids, insoluble in acetic acid.  | Chromate, dichromate.   |
| (c) <i>Ferric chloride solution.</i>  |   |
| Blue precipitate.   | Ferrocyanide.   |
| Red solution, brown precipitate on boiling.   | Acetate.  |
| Pink precipitate, soluble in hydrochloric acid, white crystals on cooling.  | Benzoate.   |
| Light yellow precipitate.   | Succinate.  |
| Pale yellow precipitate, insoluble in acetic acid.  | Phosphate.  |
| Dark brown solution.  | Ferricyanide.   |
| Blood-red coloration, extracted by ether, destroyed by mercuric chloride but not by hydrochloric acid                                     | Thiocyanate.  |
| Transitory claret coloration, destroyed by acids.   | Thiosulphate.   |
| Deep violet coloration.   | Salicylate.   |

(3) A further portion of filtrate is acidified with dilute sulphuric acid, an equal volume of ferrous sulphate solution added, and concentrated sulphuric acid carefully poured into the test-tube to form a layer :

|  |                   |
|--|-------------------|
| Brown ring.  | Nitrate, nitrite. |
| Violet ring.                                       | Iodide.           |
| Red coloration at bottom of sulphuric acid layer). | Bromide.          |

## CONFIRMATORY TESTS FOR CERTAIN ACID RADICALS.

### Chlorides, Bromides and Hypochlorites.

On distilling a chloride with sulphuric acid and a chromate, chromyl chloride volatilises, and on collecting in water, is hydrolysed to chromate, which may be detected after neutralising. Bromides give free bromine, which may be identified after conversion into bromide by means of ammonia.

In presence of free chlorine, hydrochloric acid may be detected by shaking with mercury to free from chlorine, and testing for acidity and chloride in the filtrate. If hypochlorous acid is present, the precipitate obtained with the mercury will be brown.

Manganese sulphate gives a black precipitate in alkaline solution with hypochlorites. (Chlorates do not exert their oxidising power in alkaline solution.)

### Chlorates.

(1) Dilute sulphuric acid liberates chloric acid, which gradually decomposes into perchloric acid and chlorine, and hence colours starch-iodide paper blue after standing a short time.

(2) On addition to a solution of titanous chloride, an orange solution is produced.

(3) Indigo carmine solution is bleached in the cold by *chlorate* in presence of sulphur dioxide, the presence of which is not necessary in the case of a warm solution of a *nitrate* acidified with sulphuric acid.

### Perchlorates.

(1) On reduction with titanous sulphate, or by digesting in alkaline solution with ferrous hydroxide, chlorides are produced.

Chlorides are also produced on ignition, alone or in presence of an alkali nitrite.

(2) Concentrated solutions give a white, crystalline precipitate on addition of a concentrated solution of potassium chloride.

### Bromates.

Sulphurous acid, hydrogen sulphide, zinc and an acid, etc., give bromide.

### Iodates.

(1) Hydriodic acid, or acidified potassium iodide, reduces iodic acid with liberation of iodine.

(2) Sulphurous acid causes the liberation of iodine.

(3) Pyrogallol solution gives a brown solution (not given by chlorates or bromates).

### Nitrates.

(1) Iodine is not liberated from dilute solutions of potassium iodide acidified with acetic acid until a fragment of zinc is added to reduce to nitrite.

(2) The solution under examination is mixed with three times its volume of pure, concentrated sulphuric acid, and 1 cc. of a brucine solution (0.2 grm. in 100 cc. of pure, concentrated sulphuric acid) added. Nitrates give a red coloration which rapidly changes through orange and golden yellow to yellowish green. (*Note.*—As nitrites decompose and give small amounts of nitrates on addition of sulphuric acid, they also give the brucine test.)

(3) A dilute acetic acid solution of "nitron," diphenyl-*endani*lo-dihydrotriazole, gives a white, crystalline precipitate with very dilute solutions (also given by tungstates).

(4) In absence of nitrites, nitrates may be identified, after reduction to ammonia, by Nessler solution.

(5) Indigo (carmine) solution is decolorised by free nitric acid.

#### Detection of Nitrate in Sulphuric Acid.

Although the diphenylamine test is given by many oxidising substances other than nitrates (nitrites, chlorates, etc.), it is available for the detection of traces of nitrogen acids in concentrated sulphuric acid in absence of ferric salts and of selenic acid. The reagent is prepared by dissolving 0.5 grm. of diphenylamine in 100 cc. of pure, concentrated sulphuric acid, and adding carefully 20 cc. of water. This solution is carefully poured on to the acid under examination. On standing for several minutes, the presence of nitrogen acids is shown by the production of a blue ring.

### Nitrites.

(1) Solutions acidified with sulphuric acid decolorise potassium permanganate.

(2) On addition of acidified potassium iodide, iodine is liberated, soluble in carbon disulphide to a violet solution. Detection of the iodine with starch renders this the most delicate test for nitrite in absence of other oxidising agents.

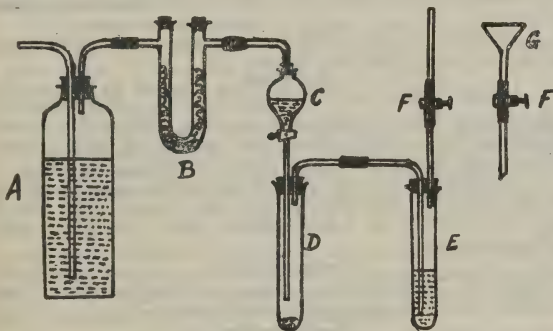
(3) The production of intensely coloured azo-compounds constitutes an extremely delicate test for nitrites in water, etc., in which case the potassium permanganate test fails, as traces of hydrogen peroxide and of ferric salts may be present.

The original reagent, suggested by Griess, was *meta*-phenylenediamine, which gives a yellow coloration or brown precipitate in presence of hydrochloric acid.

A more delicate test is to add 2 cc. of an acetic acid solution of sulphanilic acid and  $\alpha$ -naphthylamine, when within five or ten minutes a mere trace of nitrite will produce a red solution. The reagent is prepared as follows: 0.5 gm. sulphanilic acid are dissolved in 150 cc. of dilute acetic acid; 0.2 gm. of  $\alpha$ -naphthylamine are extracted with 20 cc. of water, the colourless solution decanted, and mixed with 150 cc. of dilute acetic acid. The two solutions are mixed, and preserved in the dark.

### Carbonates.

A suitable apparatus for the detection of traces of carbonate is shown in the sketch. D is a boiling tube, containing the



substance under examination, and fitted with a two-holed rubber stopper. Through one hole passes the stem of a small tap-funnel, C, the stopper of which is removed, and the top connected to a soda-lime tube, B, and this to a wash-bottle, A, containing caustic potash solution. D is connected to another boiling tube, E, as shown, which in turn is connected to a small piece of rubber tubing and screw-clamp, F. F serves to connect the boiling tube E either to the pump, or to the funnel, G. At first, both C and E are empty. The screw-clamp, F, is opened, and a slow current of air, freed from carbon dioxide, drawn through the apparatus for five minutes. The screw-clamp is closed, and the funnel G, fitted with a filter paper, inserted, and a suitable volume of baryta water poured on to the filter-paper. The tap-funnel is closed, and the soda-lime tube and wash-bottle disconnected. F is opened, and

the tap-funnel adjusted so that the baryta-water filters into the tube E. The tap-funnel and F are closed, the funnel G removed, and the apparatus again connected to the vacuum pump. About 10 cc. of dilute hydrochloric acid are introduced into the tap-funnel, which is then connected to the soda-lime tube and wash-bottle again, F is opened, and the tap-funnel adjusted so that the acid is drawn into D. A slow current of air is drawn through the apparatus for five minutes. The screw-clamp is closed, and any barium carbonate formed is easily detected by placing a piece of black paper under the boiling tube.

#### **Percarbonates.**

(1) On standing in solution, hydrogen peroxide and a bicarbonate are produced, and may be detected by the usual methods.

(2) Addition of the solid to a 25 per cent. solution of potassium iodide liberates iodine.

#### **Cyanides.**

(1) After evaporation of a cyanide with a few drops of yellow ammonium sulphide, free from thiosulphate (see Reagents), on a watch-glass, and acidifying with hydrochloric acid, ferric chloride gives a blood-red coloration.

(2) Addition of a small amount of ferrous sulphate to an alkaline solution converts cyanide into ferrocyanide, which may be detected by ferric chloride after acidifying with hydrochloric acid.

#### **Ferrocyanides.**

Insoluble ferrocyanides, such as Prussian blue, are identified after digesting with caustic soda.

#### **Ferricyanides.**

(1) Ferricyanides give a blue precipitate on addition of an acid solution of ferrous sulphate.

(2) Cadmium chloride gives a white precipitate insoluble in acids (not given by thiocyanates).

#### **Cyanates.**

(1) Dilute sulphuric acid gives carbon dioxide and ammonia, together with undecomposed cyanic acid, which has a pungent odour. The ammonium sulphate produced may be detected by warming with caustic soda solution.

(2) Cyanates may be detected in commercial cyanides by passing carbon dioxide into the solution to free from hydrocyanic acid, and then adding 25 cc. of alcohol to 1 cc. of the liquid to precipitate the carbonate. Addition of an alcoholic solution of cobalt acetate to the filtrate acidified with several drops of acetic acid gives a blue coloration (also given by thiocyanates).



### Thiocyanates (Sulphocyanides).

(1) Mercuric nitrate gives white precipitate, soluble in excess of thiocyanate.

(2) Zinc and sulphuric acid give hydrogen sulphide.

See also cyanates (2).

### Sulphates.

Benzidine hydrochloride gives a white precipitate of the sulphate (also given by tungstates).

### Sulphites.

(1) Acidified potassium permanganate solution and iodine solution are decolorised; chromates are reduced to green chromium salts.

(2) Sodium nitroprusside gives a pink coloration which becomes red on addition of zinc sulphate. The reaction is made more delicate by adding a few drops of potassium ferrocyanide, when a red precipitate is obtained (not given by thiosulphates).

(3) Zinc and dilute sulphuric acid give a yellow coloration due to the production of hydrosulphurous acid. The same result is obtained on addition of a solution of a titanous salt.

(4) Stannous chloride gradually gives a yellow precipitate.

### Sulphides.

(1) Lead nitrate, to which an excess of caustic soda has been added to give a clear solution, gives a black precipitate.

(2) Alkaline solutions give a reddish-violet coloration with a dilute solution of sodium nitroprusside.

(3) The most delicate reaction for hydrogen sulphide in water from mineral springs, etc., is the formation of methylene blue. To the liquid under examination is added one-tenth of its volume of concentrated hydrochloric acid and a small amount of dimethyl-*para*-phenylenediamine sulphate, the solution stirred, and then one or two drops of ferric chloride solution added. In the presence of amounts much less than those which can be detected by tests (1) or (2), a blue colour is produced after standing for half an hour.

### Thiosulphates.

(1) Iodine solution is decolorised.

(2) On heating with zinc and hydrochloric acid, hydrogen sulphide is produced (also given by sulphites).

(3) Silver chloride and iodide, mercurous chloride, lead sulphate, etc., are dissolved by solutions of alkali thiosulphates.

### Persulphates.

(1) Dilute solutions decompose, a large amount of ozone being formed, which may be detected by means of starch-iodide paper.

(2) In presence of an alkali, a black precipitate is obtained on addition of manganese, cobalt, etc., salts. (Persulphates are distinguished from hydrogen peroxide in that they do not decolorise permanganate solutions nor colour titanium sulphate solution yellow, nor give a blue colour with chromic acid and ether, except on standing or on heating in solution, when hydrogen peroxide is produced.)

(3) Barium chloride does not give a precipitate with fresh solutions, but on standing, more rapidly on boiling, sulphate is formed and a precipitate is obtained.

### Hydrosulphites.

(1) Hydrosulphurous acid, produced by the addition of a dilute acid, forms a yellow solution.

(2) Ammoniacal cupric sulphate gives a yellowish-red precipitate of cuprous hydride.

(3) Alkaline solutions decolorise acidulated indigo carmine; the solution obtained becomes blue on exposure to air on filter-paper.

### Selenates.

Hydrogen sulphide gives with warm solutions  $\text{SeO}_2$ , which then gives a yellow precipitate, soluble in ammonium sulphide.

### Selenites.

(1) Sulphurous acid gives a red precipitate.

(2) Copper sulphate gives a greenish-blue precipitate.

(3) Hydrogen sulphide gives a lemon-yellow precipitate, soluble in ammonium sulphide.

### Orthophosphates.

(1) Magnesia mixture gives a white crystalline precipitate with ammoniacal solutions. The precipitation of Group III metals in this test may be prevented by the addition of ammonium citrate to the solution.

(2) Ammonium molybdate (see Reagents) gives a yellow precipitate with acid solutions.

(3) Lead acetate gives a white precipitate practically insoluble in acetic acid.

(4) Uranyl acetate gives a yellow precipitate, insoluble in acetic acid.



### Metaphosphates.

(1) Magnesia mixture does not give a precipitate with dilute solutions in presence of sufficient ammonium chloride and ammonia, in the cold or on boiling.

(2) Ammonium molybdate gives a precipitate only after boiling the solution with acids to convert into orthophosphoric acid.

(3) The free acid coagulates albumen, and hence the alkali salts behave similarly on addition of acetic acid.

### Pyrophosphates.

(1) Magnesia mixture gives a white precipitate, soluble in excess of magnesium salt or of the pyrophosphate, but which is permanently precipitated by boiling.

(2) Ammonium molybdate behaves as with metaphosphates.

(3) Pyrophosphoric acid does not coagulate albumen.

### Phosphites.

(1) Mercuric chloride is reduced to mercurous chloride, and to mercury by excess.

(2) On evaporation, solution gives phosphoretted hydrogen.

(3) Zinc and an acid give phosphoretted hydrogen.

### Hyphosphites.

Silver, copper, gold and mercury salts are reduced to metal.

### Borates.

(1) The substance is mixed with calcium fluoride and concentrated sulphuric acid, and a platinum wire moistened in the mixture is held in the lower part of a bunsen flame, which is coloured green in presence of boron.

(2) On immersing turmeric paper in a solution containing free boric acid, no change occurs until the paper is carefully dried, when it becomes reddish-brown, and this colour is not changed by dilute hydrochloric or sulphuric acid (difference from the colour produced by alkalies), but is turned bluish-black by caustic alkalies.

*Note.*—This test is also given by hydrochloric acid solutions of molybdic and titanous acids.

(3) Concentrated solutions give a precipitate of boric acid with hydrochloric acid.

### Silicates.

(1) On evaporating to dryness with hydrochloric acid, a residue of silicic acid is obtained, which becomes blue on heating with cobalt nitrate on charcoal.

(2) The addition of an ammonium salt precipitates gelatinous silicic acid.

### Hydrofluosilicates (Silicofluorides).

(1) Potassium chloride gives a gelatinous precipitate of potassium hydrofluosilicate in presence of an equal volume of alcohol.

(2) Ammonia gives a precipitate of silicic acid.

(3) On heating with concentrated sulphuric acid in a *platinum* vessel, silicon fluoride is produced (not given by fluorides), and may be detected by the formation of a white precipitate on the end of a moist glass rod held in the vapour.

### Arsenites.

(1) In presence of sodium bicarbonate, iodine solution is decolorised.

(2) On warming with copper foil and hydrochloric acid, a deposit of copper arsenide is obtained (not given by arsenates).

(3) In presence of concentrated hydrochloric acid, stannous chloride gives a black precipitate on warming. (Also given on addition of titanous chloride.)

(4) Copper sulphate gives a green precipitate on addition of ammonia, soluble in excess. This precipitate of cupric hydrogen arsenite forms (red) cuprous oxide on heating with caustic soda solution.

### Arsenates.

(1) In presence of ammonia and ammonium chloride, magnesium chloride gives a white, crystalline precipitate (not given by arsenites).

(2) In presence of a large excess of ammonium molybdate, (see Reagents), a yellow, crystalline precipitate is obtained on boiling (also given by arsenites, due to their oxidation to arsenate by the nitric acid in the ammonium molybdate reagent).

(3) Hydrogen sulphide first gives a white precipitate of sulphur in presence of hydrochloric acid and then a bright yellow precipitate of arsenic sulphide.

### Antimonates.

On addition of potassium iodide to an acid solution, iodine is liberated. This test is not given by the alkali metantimonites, which contain  $Sb^{III}$  in place of  $Sb^{V}$ . In alkaline solution, antimonates give with silver nitrate a black precipitate of silver oxide, soluble in ammonia, whereas the metantimonites give a precipitate which is not completely soluble in ammonia as it also contains metallic silver.

### Chromates.

(1) After boiling with hydrochloric acid and alcohol, ammonia gives a bluish-green precipitate.

(2) The test for hydrogen peroxide, involving the production of perchromic acid, may also be used in identifying chromates after addition of sulphuric acid. Traces of chromate can only be detected by using ether free from alcohol.

### Formates.

Mercuric chloride gives a precipitate of mercurous chloride.

### Acetates.

(1) On warming the solid with a mixture of one part of alcohol and two parts of concentrated sulphuric acid, the smell of ethyl acetate is produced.

(2) On heating with arsenious oxide give cacodyl oxide (*extremely poisonous*)

### Oxalates.

(1) Calcium chloride gives a white precipitate, soluble in dilute hydrochloric and nitric acids (reprecipitated by ammonia), but insoluble in acetic acid.

(2) On warming in presence of sulphuric acid, dilute potassium permanganate is decolorised.

(3) On heating with manganese dioxide and sulphuric acid, carbon dioxide is produced.

### Tartrates.

(1) Calcium chloride gives a white precipitate, which only forms slowly in dilute solutions (especially in presence of ammonium chloride). The precipitate is soluble in acetic acid, and after washing is dissolved by cold caustic alkalies, being reprecipitated on heating, and redissolved on cooling.

(2) Silver nitrate gives a white precipitate. The supernatant liquid is decanted, water added, and precipitate dissolved in *just sufficient* very dilute ammonia. On placing the solution in a water-bath at 60–70°C., a silver mirror is formed.

*Note.*—In presence of other acids (except borate), tartrates may be precipitated by adding solid potassium carbonate to a concentrated solution until alkaline, and carefully acidifying with glacial acetic acid. The precipitated acid potassium tartrate is washed, dissolved in dilute caustic soda, neutralised, and the test carried out as in (2) above.

(3) A neutral or acid solution, to which has been added a small amount of ferrous sulphate, gives, on addition of a few drops of hydrogen peroxide, and then an excess of caustic

soda, a deep violet or blue coloration, intensified by addition of two or three drops of ferric chloride.

(4) On warming with a 1 per cent. solution of resorcinol in concentrated sulphuric acid, a red coloration is produced.

#### **Tartrates, Malates and Citrates.**

In presence of these hydroxy-acids, ferric chloride does not give a precipitate on addition of alkali.

### **SPECIAL SEPARATIONS OF ACID RADICALS.**

#### **Chloride, Bromide, Iodide and Cyanide.**

If a preliminary test with chlorine water has shown that a halide other than chloride is present, it is necessary to proceed as follows :

If present, *cyanide* is precipitated by adding a slight excess of nickel sulphate to neutral solution (*ferricyanides* are precipitated afterwards by adding ferrous sulphate); it is then boiled with a small amount of halogen-free caustic soda, and filtered. The filtrate is acidified with dilute sulphuric acid, and divided into two portions.

One portion of the acidified solution and a layer of chloroform are poured into a test-tube, and chlorine water added gradually, shaking after each addition. Violet solution indicates *iodide*. (Traces of iodide in presence of bromide are best detected by adding nitrite to a solution containing sulphuric acid, when only iodine is liberated.) Further addition of chlorine water decolorises the chloroform solution, which, however, becomes orange in presence of *bromide*.

On gradual addition of silver nitrate to the other half of the acidified filtrate, bromide and iodide are first precipitated, and by filtration after each addition of silver nitrate the presence of *chloride* is shown by the final precipitate being white.

#### **Halides and Thiocyanate.**

These are first precipitated with an excess of silver nitrate, and the precipitate digested on a water-bath with concentrated nitric acid for an hour, when only the silver halides remain undissolved.

#### **Chloride, Chlorate and Perchlorate.**

The *chloride* is precipitated in one portion of solution by adding an excess of silver nitrate; after filtering, the filtrate is acidified with sulphuric acid, a small piece of zinc added, and warmed. White precipitate indicates *chlorate*. The remainder of the solution is reduced with sulphur dioxide, excess boiled off, and all chloride present precipitated as silver chloride. The filtrate is tested for *perchlorate*.

### Chlorate and Hypochlorite.

Chlorate prepared by the electrolytic process may be tested for traces of hypochlorite by adding to 100 cc. of a 1 per cent. solution, prepared in the cold, 5 cc. of a mixture of a 10 per cent. cadmium iodide solution and a starch solution. Traces of hypochlorite immediately produce a blue colour.

(Hypochlorites give a precipitate of silver chloride on addition of silver nitrate or sulphate, but the solution then contains silver chlorate.)

### Iodide and Iodate.

*Iodide* is tested for by means of fresh (neutral) chlorine water and carbon disulphide (chloroform is generally acid). Liberation of iodine on acidifying in presence of an iodide, indicates *iodate* (in absence of other oxidising agents).

### Chlorate and Nitrate.

Solution is boiled with caustic soda to free from ammonium salts, aluminium dust added, and solution boiled. Evolution of ammonia indicates *nitrate* (also given by *nitrite*). Solution is acidified, and tested for chloride, the presence of which indicates *chlorate* in absence of chloride in the original (if present, chloride is eliminated by means of silver sulphate).

### Nitrite and Nitrate.

Moderate amounts of *nitrite* are readily detected by means of potassium permanganate or iodide in presence of sulphuric acid.

On acidifying a solution of ferrous sulphate with dilute sulphuric acid and carefully pouring the solution on to the surface, a brown ring is formed in presence of a *nitrite*. The detection of *nitrate* by this test necessitates the use of concentrated sulphuric acid, and the test may be carried out after destroying the nitrite by boiling with ammonium chloride, or with a concentrated solution of urea in presence of sulphuric acid. (*Note.*—Traces of nitrate may be formed by oxidation during this process.)

*Meta*-phenylenediamine, or, better, the sulphanilic acid and  $\alpha$ -naphthylamine reagent (see Reagents), is used for detecting *nitrite*.

Brucine may be used for detecting *nitrate* (see note above; the reaction between nitrite and concentrated sulphuric acid leads to the formation of traces of nitric acid). If the diphenylamine coloration is very decided after destroying the nitrite, the presence of *nitrate* may be assumed.

### Separation of the Sulphur Acids.

Alkali sulphites, hydrosulphites, sulphides and polysulphides in weak alkaline solution decolorise aqueous solutions of magenta and of malachite green, or, better, a mixture of three volumes of 0.25 per cent. magenta solution and one volume of a 0.25 per cent. malachite green solution. The colour returns on addition of formaldehyde or acetaldehyde.

Bisulphides, thiosulphates and thionates do not decolorise the above dyestuff solution.

Carbon dioxide is passed into the solution until a drop gives practically no red colour with phenolphthalein. A portion of the solution is tested for *sulphide* with sodium nitroprusside. If present, it is removed by shaking with an excess of cadmium carbonate and filtering. A portion of the filtrate is then tested with the above dyestuff solution, when decolorisation indicates the presence of a *sulphite*; a further portion of the filtrate is acidified with dilute hydrochloric acid and boiled, when a precipitation of sulphur indicates the presence of a *thiosulphate*.

An alternative method is based on the solubility of barium *thiosulphate* and the insolubility of the *sulphate* and *sulphite*, the latter being identified by the addition of bromine water to the hydrochloric acid extract.

### Sulphite and Carbonate.

The precipitation of barium sulphite prevents the direct detection of carbon dioxide by baryta water. The apparatus used for detection of traces of carbonate may be used for detection of carbonate in presence of sulphite, provided an extra wash-bottle containing a solution of potassium dichromate and dilute sulphuric acid (to remove sulphur dioxide) be interposed between the two boiling tubes.

### Chromate and Dichromate.

An excess of barium chloride solution is added to precipitate barium chromate; an acid filtrate indicates a *dichromate*.

The dichromate may be precipitated by addition of methylene blue; further precipitate on addition of several drops of dilute sulphuric acid to the filtrate containing an excess of methylene blue indicates presence of a *chromate*.

## II. Metallic Radicals (Cations).

PRELIMINARY TREATMENT OF SUBSTANCE IN PRESENCE OF PHOSPHATE, BORATE, SILICATE, FLUORIDE, OXALATE, Etc.

The presence of phosphate, borate, silicate, fluoride, and cyanide, and also of certain organic acids, *e.g.*, oxalic,



tartaric and citric acids, interferes with the group tests, and hence these acids may be removed before proceeding to Group III (except cyanides, which are removed before commencing the group tests), as follows :

*Silicate.* The substance is evaporated with concentrated hydrochloric acid, and finally heated in an air oven to  $150^{\circ}\text{C}$ . to render the silica insoluble. The residue is then extracted with dilute hydrochloric acid.

*Phosphate* is removed from Group III precipitate by one of the following methods :

(1) The precipitate is boiled with caustic soda, and filtered. Ammonium chloride is added to the filtrate, which is then boiled. White precipitate indicates *aluminium*. The precipitate is washed and dissolved in the smallest possible amount of dilute hydrochloric acid, ammonium carbonate added to the cold solution until it becomes turbid, and very dilute hydrochloric acid added drop by drop until it becomes clear. An equal volume of ammonium acetate solution is added, and then ferric chloride drop by drop until a reddish liquid is obtained. The solution is boiled for several minutes and filtered.

The precipitate is examined for *aluminium* and *chromium* by the usual Group III separation. The filtrate is boiled with ammonia and ammonium chloride, filtered, any precipitate obtained examined for *chromium*, and the filtrate added to that for Group IV.

The original substance is examined for *iron* as suggested in Group III separation table

(2) The filtrate from Group II, after removal of sulphuretted hydrogen, is evaporated to dryness three times with 10 cc. of concentrated nitric acid to remove hydrochloric acid, dissolved in 10 cc. of nitric acid and 1 grm. pure tinfoil added. When the action has ceased, the mixture is poured into 100 cc. of cold water and allowed to stand over-night. The clear liquid is siphoned off, and used for Group III.

*Fluoride* and *cyanide* are removed by evaporating substance with concentrated sulphuric acid in a platinum capsule.

*Oxalate*, *tartrate*, and other non-volatile organic substances are destroyed by igniting the substance in a platinum capsule, extracting the carbonates formed by means of concentrated hydrochloric acid, moistening the residue with concentrated ammonium nitrate solution, and then continuing to heat until all carbonaceous matter has burnt off, any insoluble residue being fused with potassium bisulphate.

# THE SEPARATION OF THE GROUPS.

(N.B.—The colours of the precipitates formed are only indications of the nature of the radicals present, as the presence of one metallic radical may cause the masking of the colour of the precipitate given by another metallic radical).

## I. Acidify with HCl.

White ppt.

LEAD

SILVER, or

MERCUROS

II. Pass  $H_2S$  into soln.

Warm precipitate with ammonium sulphide

Oxidise soln. with bromine water.

Eliminate phosphates, etc.

III. Add  $NH_4Cl$  and  $NH_4OH$ .

Residue

(1) Soluble in  $HNO_3$ :

Yellow ppt. CADMIUM

Black ppt. BISMUTH, COPPER, or LEAD

(2) Insol. in  $HNO_3$ :

Black ppt. Sol. in  $HCl + KClO_3$ , MERCURIC

Filtrate

On acidifying with  $HCl$ :

Orange ppt. ANTIMONY

Brown ppt. STANNOUS

Yellow ppt. STANNIC

Bright yellow ppt. ARSENIC

Brown ppt. IRON

Violet or green ppt. CHROMIUM

White ppt. ALUMINIUM

Ppt. (1) Sol. in  $HCl$ .

White ppt. frequently discolored, ZINC

Pink ppt. MANGANESE

(2) Insol. in  $HCl$ , sol. in conc.  $HCl + KClO_3$

Black ppt. COBALT or NICKEL

IV. Pass  $H_2S$  into soln.

V. Add ammonium carbonate to filtrate.

White ppt. CALCIUM, STRONTIUM, or BARIUM

VI. Add sodium phosphate to soln., White ppt. MAGNESIUM

In original substance:

SODIUM and POTASSIUM by flame tests.

AMMONIUM by  $NaOH$

Group I.

Group II.

Group IIa.

Group III.

Group IV.

Group V.

Group VI.



## Test for Ammonium Salts.

An excess of caustic soda is added, and the solution warmed. Evolution of ammonia indicates presence of an ammonium salt.

### Group I

In presence of an arsenate, chromate, dichromate, manganate, or permanganate, reduce with sulphur dioxide, and boil off the excess. Acidify solution with hydrochloric acid.\*

Filter and reserve *filtrate* for Group II.

Extract white *precipitate* with hot water, and filter hot.

#### RESIDUE.

Wash with hot water until filtrate gives no ppt. with silver nitrate soln. Treat residue with ammonia, and filter immediately.

#### FILTRATE.

White crystals may separate on cooling. Add potassium chromate and sodium acetate to soln. Yellow ppt., soluble in caustic soda :

**LEAD.**

#### RESIDUE.

Wash, and dissolve in dilute hydrochloric acid to which has been added a crystal of potassium chlorate, and almost neutralise with caustic soda. Boil with a piece of copper foil. Metallic deposit, gives mirror of globules of mercury on heating in an ignition tube :

**MERCURY(-OUS).**

#### FILTRATE.

Acidify with nitric acid. White curdy ppt., filter, residue soluble in sodium thiosulphate soln., the soln. darkening on heating :

**SILVER.**

\* White ppt., sol. in excess, indicates bismuth or antimony, or the presence of aluminate, stannate, antimonate or zincate. Ppt. of sulphur indicates presence of a thiosulphate or polysulphide. Gelatinous ppt. indicates an alkali silicate. Amorphous ppt., white when cold and yellow hot, indicates an alkali tungstate. White ppt., soluble in hot water, will be obtained in presence of much borate. Complex cyanides give a ppt. of an insoluble simple cyanide.

Evaporate to dryness and use hydrochloric acid extract for Group II.

### Group II.

Warm *filtrate* from Group I, pass in a slow current of hydrogen sulphide, filter, dilute somewhat, and pass hydrogen sulphide into the warm filtrate. Filter, if necessary, through same filter paper, and reserve *filtrate* for Group III. Light yellow precipitate of sulphur indicates presence of an

oxidising agent (ferric salt, hydrogen peroxide, etc.). Wash precipitate with fresh hydrogen sulphide solution, rejecting filtrate, and then warm with 5 cc. of yellow ammonium sulphide. Filter, and reserve *filtrate* for Group IIa.

Wash residue with water containing ammonium sulphide, and then with fresh hydrogen sulphide solution, rejecting filtrates. Digest the precipitate in an evaporating basin with 5 cc. of nitric acid (1:1). Dilute somewhat, and filter.

#### RESIDUE.

Pierce the filter-paper, and wash ppt. into an evaporating dish with 1 cc. of water and then with 5 cc. of warm, dilute hydrochloric acid to which has been added a crystal of potassium chlorate. Evaporate to 2 cc., filter if necessary, and add stannous chloride solution to the filtrate. White or grey ppt.:

#### MERCURY(-IC).

#### FILTRATE.

Evaporate to 2-5 cc. in an evaporating dish, add 5 cc. dilute sulphuric acid, and evaporate almost to dryness. Stir residue with 5 cc. of cold dilute sulphuric acid, and filter.

White ppt.  
Soluble in  
ammonium  
acetate solution,  
reprecipitated on  
addition of  
sulphuric acid:  
**LEAD.**

Filtrate.  
Add a slight  
excess of ammonia,  
and filter.

White ppt.

Solution in hydrochloric acid gives on addition of water a white ppt.:

#### BISMUTH.

Blue filtrate:

#### COPPER.

In presence of copper, acidify with dilute sulphuric acid, and boil with iron wire. Filter rapidly from precipitated copper, etc. Pass hydrogen sulphide into filtrate. Yellow ppt.:

#### CADMIUM.

*Note.*—Traces of copper are best detected by evaporating some of the *original* substance almost to dryness with dilute sulphuric acid, filtering if necessary, and then adding 1 cc. of a dilute solution of titanous sulphate to the filtrate. Pink opalescence or precipitate of metal indicates presence of copper. (Black precipitates are obtained in presence of arsenic or platinum; a purple solution is obtained in presence of gold.)

## Group IIa.

Dilute *filtrate*, obtained by warming precipitate with ammonium sulphide in Group II, with an equal volume of water, and acidify with dilute hydrochloric acid. Boil, allow precipitate to settle, and decant off as much liquid as possible. Filter and wash the precipitate, rejecting the filtrate.

Warm the precipitate, which contains sulphur, with ammonium carbonate solution, adding solid ammonium carbonate if necessary, and filter.

## RESIDUE.

Boil with concentrated hydrochloric acid. If necessary filter from sulphur after dilution. Concentrate to a very small volume, and place several drops of liquid on a piece of suitably bent platinum foil, on which is a fragment of zinc foil. After some seconds remove the zinc.

Black stain on platinum foil, insoluble in hydrochloric acid, but soluble in ammonium sulphide, the solution leaving an orange residue on evaporation:

## ANTIMONY.

Place zinc and platinum foil in test-tube with remainder of liquid, and after hydrogen has been evolved rapidly for a short time, filter if necessary, and add mercuric chloride solution to filtrate. White or grey ppt.:

## TIN.

## FILTRATE.

Acidify with hydrochloric acid, filter, and wash ppt. Pierce filter-paper, wash ppt. into an evaporating dish, and dissolve in concentrated nitric acid. Evaporate almost to dryness, add sulphur dioxide solution and then 5 cc. of cold dilute hydrochloric acid, and a piece of copper foil, and warm. Metallic deposit (*Reinsch's test*), gives white sublimate on heating in ignition tube:

## ARSENIC.

(An alternative method is to dissolve the ppt. of arsenic sulphide by warming with hydrogen peroxide and ammonia. Boil, and add ammonium chloride and magnesium chloride. White crystalline ppt. indicates *arsenic*).

Marsh's Test. Traces of *arsenic* and *antimony* are detected by pouring into a hydrogen generator the solution obtained by evaporating the nitric acid solution just to dryness and dissolving in cold hydrochloric acid. The arsenic and antimony hydrides burn with the hydrogen. The production of a brown stain, soluble in hypochlorite, on a cold porcelain crucible lid held in the flame, indicates the presence of *arsenic*. In case the stain does not dissolve readily in hypochlorite, it indicates the presence of *antimony*. (Nitrates, chlorates, etc, must be absent in this test.)

An alternative method of detecting *antimony* or *tin* in the residue is as follows : Boil the solution in hydrochloric acid with iron wire for several minutes, filter off precipitated antimony, etc., and add mercuric chloride to filtrate to test for *tin*. Dissolve residue in hydrochloric acid (1 : 1) containing a small crystal of potassium chlorate, boil, dilute somewhat, and pass in hydrogen sulphide. Orange precipitate indicates presence of *antimony*.

### Group III.

*Phosphates, etc., must be removed before proceeding to Group III.*

Oxidise *filtrate* from Group II with bromine water, boil off the excess, and add a few cc. of ammonium chloride and an excess of ammonia.

Filter immediately, and reserve *filtrate* for Group IV. Wash precipitate, pierce the filter-paper, and wash precipitate into a boiling tube. Add sodium peroxide in small amounts, boil for two or three minutes, allow to cool, dilute somewhat, and filter.

| RESIDUE.   | FILTRATE.   |
|--|---|
| Dissolve in dilute hydrochloric acid, and add potassium ferrocyanide solution. | Add ammonium sulphate (solid) and filter.   |
| Blue ppt. :  |   |
| IRON.  |   |
| Test original substance in hydrochloric or sulphuric acid solution with :      |   |
| (a) Potassium ferrocyanide solution :  | White gelatinous ppt., gives light blue mass on heating with cobalt nitrate on charcoal: ALUMINIUM.   |
| Blue ppt. : FERRIC.  | Yellow filtrate. Boil with excess caustic soda until free from ammonia. Acidify with acetic acid, and add silver nitrate solution. Red ppt. CHROMIUM. |
| (b) Potassium ferricyanide solution.   |   |
| Blue ppt. : FERROUS.   |   |

*Note.*—Traces of *iron* may be detected by reducing to the *ferrous* condition with zinc dust (free from iron), filtering, adding citric acid followed by an excess of ammonia, and then *diamethylglyoxime*, which gives a pink colouration with *ferrous iron*.

## Group IV.

Add ammonium sulphide to two drops of *filtrate* from Group III. In case a precipitate is obtained, warm remainder of *filtrate*, and pass a current of hydrogen sulphide, filter, and reserve *filtrate* for Group V. Wash precipitate several times with water containing ammonium sulphide and then with cold dilute hydrochloric acid.

## RESIDUE

Test by borax bead for

COBALT and NICKEL

As the presence of a small amount of cobalt will mask the presence of even large amounts of nickel in the borax bead, pierce filter-paper, and dissolve ppt. in hydrochloric acid to which has been added a crystal of potassium chlorate. Evaporate almost to dryness. Dissolve the residue in 5 cc. of water, add an equal volume of ammonium chloride soln., and several drops of ammonia.

Divide soln. into two portions :

To one portion add 1 cc. of a soln. of the sodium salt of *a*-benzildioxime (or an alcoholic soln. of *a*-dimethylglyoxime). Pink ppt. :

NICKEL.

To the other portion add 1 cc. of a soln. of the sodium salt of *a*-nitroso- $\beta$ -naphthol. Orange coloration, or ppt., not destroyed by just acidifying with dilute sulphuric acid :

COBALT.

## FILTRATE.

Boil with an equal volume of caustic soda solution. Filter.

## RESIDUE.

Test by borax bead for

MANGANESE.

Confirm by converting into permanganate by digesting with potassium persulphate and a few drops of silver nitrate.

## FILTRATE.

Acidify with acetic acid and pass in hydrogen sulphide. White ppt., becomes green on heating with cobalt nitrate on charcoal :

ZINC.

(Note.—Traces of *nickel* in cobalt salts may be detected by adding concentrated ammonia soln., oxidising with hydrogen peroxide, boiling to destroy the excess, and then adding the nickel reagent. After filtering, the residue is washed with hot water. Pink residue indicates presence of *nickel*).

## Group V.

If *filtrate* from Group IV is brown, due to presence of nickel, acidify with acetic acid, warm, and filter.

In case solution is not quite clear, add bromine water to oxidise suspended sulphur, and boil off the excess. (This is to be avoided if possible as it may cause the precipitation of traces of barium sulphate, etc.)

Concentrate the solution to 5 cc., and to the clear solution add an excess of ammonia and then ammonium carbonate, warm to about 60–70°C., filter, and reserve *filtrate* for Group VI.

Wash residue with water, and then treat with dilute nitric

acid, collecting filtrate in an evaporating basin. Evaporate filtrate *just* to dryness.

(1) Dissolve a *small portion* of residue in water, and add calcium sulphate solution :—

No ppt. even on standing.

Gradual formation of ppt.

Immediate ppt.

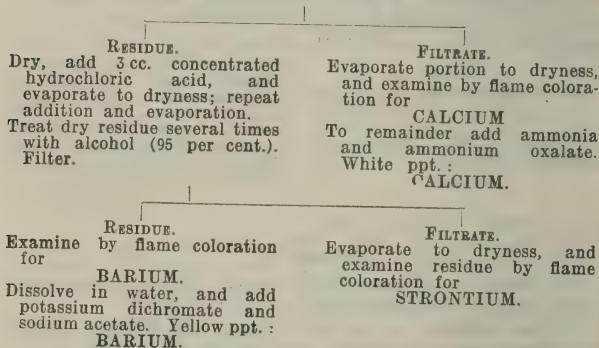
Calcium may be present. Barium and strontium absent.

Strontium present; possibly also calcium. Barium absent.

Barium present; possibly also strontium and calcium.

Calcium may be confirmed by freeing *another* small portion of residue from barium and strontium, if present, by adding dilute sulphuric acid to the solution in water, allowing to stand for several minutes, filtering, and then adding ammonia and ammonium oxalate to the filtrate. White ppt. indicates *calcium*.

(2) In case addition of calcium sulphate produces a precipitate, the remainder of the residue is stirred with three or four portions of 2-3 cc. of alcohol (95 per cent.), decanting the alcohol through a filter-paper moistened with alcohol.





## Group VI.

(1) To approximately half of the *filtrate* from Group V add a small amount of ammonia, and ammonium chloride, if necessary, to dissolve any precipitate formed. Add sodium phosphate and a few cc. of concentrated ammonia solution. Allow to stand for some time if precipitate is not formed immediately.

White crystalline ppt.

MAGNESIUM.

(2) Evaporate a small portion of the *filtrate* from Group V to dryness, and examine by flame coloration for POTASSIUM, SODIUM, and LITHIUM. Confirm by testing *original* substance.

(3) Evaporate the remainder of the solution to dryness in a porcelain or platinum dish and gently ignite the residue to expel ammonium salts. Dissolve the residue in a small amount of water, disregarding any residue of basic magnesium salt, and add barium hydroxide solution until strongly alkaline. Heat to boiling, filter, make the filtrate just acid with hydrochloric acid, and precipitate the barium with ammonia and ammonium carbonate. Filter, evaporate the filtrate to dryness, heat the residue gently to expel ammonium salts, take up with water, and repeat the precipitation with ammonium carbonate, filter, evaporate to dryness and remove ammonium salts. Dissolve the residue in a small amount of water, filter and evaporate the filtrate to dryness. (None of these operations should be performed in glass owing to the danger of extracting alkalis.) Add to the residue 10 cc. of 2N perchloric acid, and evaporate carefully until dense fumes of perchloric acid are evolved. Cool and add 20 cc. of alcohol. (If the perchloric acid-ammonia solution be heated there is extreme danger of a violent explosion). If necessary, add 2-3 cc. more perchloric acid, stir gently, and filter. Wash the ppt. with alcohol. Pass dry hydrochloric acid gas through the alcoholic filtrate to saturation, filter off the precipitated sodium chloride, wash with alcohol, and dissolve the residue in 1 cc. water. Add 2 cc. potassium pyroantimonate solution, and allow to stand over-night. A *crystalline* ppt. indicates sodium.

(The pyroantimonate solution is prepared by treating 20 grms. of the commercial salt with a litre of boiling water, boiling till nearly all the salt has dissolved, cooling quickly, adding 30 cc. KOH and filtering.)

Examine *original* substance for potassium as follows :

Boil with a solution of sodium carbonate (free from potassium) until free from ammonium salts, filter, add a

slight excess of acetic acid to the filtrate and then a recently prepared one per cent. solution of sodium cobaltinitrite.

Yellow ppt.

POTASSIUM.

An alternative method is to add a strong solution of sodium acetate, and then tartaric acid. White crystalline precipitate, best obtained by shaking in presence of alcohol, indicates POTASSIUM

## Notes on the Group Separations.

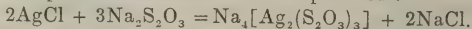
In order that arsenates, chromates, etc., should be precipitated in the course of the groups, it is essential to reduce with sulphur dioxide to arsenites, chromic salts, etc.; otherwise chromate might give a green precipitate in Group II, and arsenic would only be precipitated, together with much sulphur, after a slow reduction with hydrogen sulphide. As this leads to the production of sulphuric acid in the solution, and hence would cause the precipitation of the insoluble sulphates of lead, barium, etc., this method of treatment must be avoided in presence of these metals. In such cases chromate is reduced by boiling with hydrochloric acid and alcohol, and arsenate by hydrogen sulphide, taking great care to ensure its complete reduction and removal (see notes on Group II).

### *Group I.*

Silver chloride dissolves in ammonia to form the complex salt:  $[\text{Ag}(\text{NH}_3)_2]\text{Cl}$ , whereas mercurous chloride gives the insoluble compound  $\text{Hg}(\text{NH}_2)\text{Cl}$  mixed with metallic mercury.

Owing to the slight reducing action of mercurous chloride in presence of ammonia, a small quantity of silver might not be detected in presence of large amounts of mercurous chloride, as it would remain insoluble as metallic silver. This may be prevented by oxidising the mixture of the two chlorides with bromine water, when only the silver chloride remains undissolved. Mercury is detected in the filtrate by means of stannous chloride.

The solubility of silver chloride in sodium thiosulphate depends upon the formation of a complex ion:



On warming in presence of an excess of thiosulphate, the black silver sulphide is produced.

### *Group II.*

Care must be taken not to have the solution too strongly acid, as this prevents the precipitation of cadmium sulphide. On the other hand, the solution must contain a moderate



amount of hydrochloric acid, to prevent the formation of a colloidal suspension of arsenic sulphide, and to keep bismuth and antimony in solution. It has been found that arsenic is most readily precipitated if the concentration of hydrochloric acid is above 2N, whereas the concentration of the acid must be below N/2 to obtain complete precipitation of other members of this group, notably cadmium, antimony, and tin. To prevent metals of later groups from being precipitated, the concentration of acid must be above N/8.

On passing hydrogen sulphide into the solution, mercuric salts may give a white precipitate of a chloresulphide which passes through yellow and brown to black, and lead salts frequently give a reddish precipitate of chloresulphide which becomes black on warming and further saturating with hydrogen sulphide.

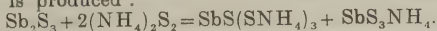
As copper sulphide is somewhat soluble in yellow ammonium sulphide, the titanous sulphate test must be carried out with the *original* substance (in absence of nitric acid), unless sodium sulphide is used, in which the copper sulphide is not soluble.

An alternative delicate test for copper is given by the precipitation of its ferrocyanide in acetic acid solution.

#### *Group IIa.*

Yellow "ammonium sulphide" contains polysulphides, thiosulphate, etc.

The solubility of the sulphides of this group in ammonium sulphide is due to the formation of the salts of complex thio-acids, *e.g.*, ammonium thioarsenite,  $\text{As}(\text{SNH}_4)_3$ . The solution should not be boiled as it is liable to lead to the precipitation of the red oxysulphide of antimony ( $\text{Sb}_2\text{S}_2\text{O}$ ) by oxidation of the thioantimonite  $\text{Sb}(\text{SNH}_4)_3$ . In case yellow ammonium sulphide is used, ammonium thioantimonate is produced :



Stannous sulphide is not soluble in colourless ammonium sulphide, but is converted into the soluble stannic compound by yellow ammonium sulphide. On this account it is necessary to test in the *original* substance for the condition of the tin as follows :

A solution is prepared in the cold containing hydrochloric acid. Mercuric chloride is added, when white or grey precipitate indicates presence of a *stannous* compound; in case no precipitate is obtained, the presence of a *stannic* compound may be assumed.

The metallic deposit obtained on the copper foil is probably an arsenide,  $\text{Cu}_5\text{As}_2$ .

## Group III.

Before adding the group reagent, it is necessary to oxidise any ferrous salt present, which may have been produced from a ferric salt by hydrogen sulphide. It follows that the tests for ferrous and ferric ions must be carried out with the *original* substance. Fresh solutions of potassium ferrocyanide and ferricyanide should be used, as these solutions decompose on standing. In case iron has been found to be present, but neither of these reagents gives any reaction, the presence of the iron as ferrocyanide or ferricyanide may be suspected.

Before oxidising, as much hydrogen sulphide as possible should be removed by boiling, to avoid its oxidation to sulphuric acid, which might cause the precipitation of barium, etc. In case the solution is not quite clear after boiling with an excess of bromine water, it is filtered, and the residue examined by flame coloration (as suggested for barium sulphate, see "Dry-way tests").

It is essential to free completely from bromine, as otherwise a hydrated manganese oxide will be precipitated on addition of ammonia. In presence of much nitric acid (hence the advantage of using bromine water), or even on exposure of the warm ammonia solution to air, manganese may be precipitated as a brown powder, readily distinguished by its character from ferric hydroxide.

The addition of ammonium chloride is necessary to keep magnesium, etc., in solution, and also to render the precipitation of aluminium hydroxide more complete (probably due to the conversion of the colloidal solution (*aqua sol*) of aluminium hydroxide into the insoluble *gel*). Even in presence of ammonium chloride, it is essential to boil for several minutes to complete the precipitation of chromium.

On boiling with sodium peroxide, chromium hydroxide is oxidised to chromate, and the aluminium hydroxide dissolves in the caustic soda formed to give sodium aluminate. Addition of ammonium sulphate to the filtrate frees the solution from caustic alkali, forming ammonia, in which the aluminium hydroxide is not soluble.

As caustic soda frequently contains aluminate and silicate, it is advisable to carry out a "blank" on the caustic soda solution in case only traces of aluminium are found. A confirmatory test for aluminium is as follows: To about 5 cc. of the neutral or acid solution under examination is added

1 cc. of a filtered solution of Alizarin S, and then ammonia until the solution is alkaline, as shown by the purple colour. The solution is boiled for a few moments, allowed to cool, and then acidified with dilute acetic acid, when a red coloration or precipitate remaining is conclusive evidence of the presence of aluminium (see Atack, *J. Soc. Chem. Ind.*, Sept. 1915).

The necessity for removing phosphate is due to the phosphates of certain metals of later groups being soluble in hydrochloric acid, but being reprecipitated on addition of ammonia. Hence they would appear in Group III, *e.g.*, calcium phosphate might be mistaken for the aluminium hydroxide precipitate.

For similar reasons fluorides must be removed before proceeding to Group III; for example, precipitated calcium fluoride is soluble in hydrochloric acid, but would be reprecipitated on addition of ammonia. As is also the case with borates, fluorides would only be precipitated incompletely in Group III, and metals present as borates or fluorides may frequently be identified as usual in the later groups.

The method of separating phosphate as a basic tin phosphate before proceeding to Group III is more satisfactory than separating as basic ferric phosphate in presence of chromium, but manganese is carried down with the precipitate, which is often difficult to filter.

The removal of organic acids before Group III is necessary owing to their tendency to form complex ions with ferric, aluminium, etc., salts which do not give a precipitate with ammonia. Thus aluminium hydroxide is soluble in neutral tartrates, forming a compound containing a complex negative ion.

Oxalates must be removed, as addition of ammonia would precipitate calcium, strontium and barium as oxalates in Group III.

As ammonium carbonate is frequently present in the ammonia, traces of Group V metals may be carried down in this group; in such a case, dissolve the precipitate in dilute hydrochloric acid, and re-precipitate by adding ammonia drop by drop. The ammonia should also be tested for sulphate, which would precipitate metals of Group V.

*Note.*—In presence of large amounts of cobalt, or if small amounts of zinc are to be detected, it is necessary to precipitate the metals of Groups III and IV together, by

adding ammonia and ammonium chloride and then passing in hydrogen sulphide, filtering, and washing with water containing ammonium sulphide.

Cobalt and nickel are obtained as sulphides insoluble in cold 10 per cent. hydrochloric acid, whereas the remainder of the precipitate is soluble. The filtrate is then oxidised with bromine, and iron, chromium, and aluminium hydroxides precipitated by almost neutralising with sodium carbonate, adding precipitated barium carbonate and then allowing to stand, with occasional shaking, for one hour. The precipitate is filtered off, and examined as in the usual Group III separation. The solution contains manganese, zinc, and traces of barium (from the barium carbonate), and is examined for manganese and zinc as Group IV separation.

A disadvantage of this joint method of precipitation is that phosphates of the metals of later groups may be precipitated, and cause difficulties in the separation. Phosphates of the metals of Group IV will have been converted into sulphides by digesting with ammonium sulphide.

#### *Group IV.*

It is advisable to use hydrogen sulphide in this group, as ammonium sulphide frequently contains sulphate, which would cause the precipitation of barium, etc. The use of hydrogen sulphide further avoids the dissolution of nickel sulphide, which is not soluble in colourless ammonium sulphide.

In presence of much ammonia, it is necessary to boil for some time to effect complete precipitation of the manganese sulphide.

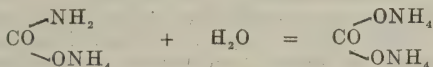
Although nickel and cobalt sulphides are insoluble in dilute hydrochloric acid, they are not precipitated in Group II. This behaviour is ascribed to a change in the state of aggregation of these sulphides immediately after precipitation.

As cobalt and nickel sulphides oxidise rapidly to the soluble sulphates, it is necessary to wash with water containing ammonium sulphide, and to avoid exposing the precipitate to air. Traces of nickel generally pass into the solution with the zinc and manganese.

As manganese sulphide is soluble in acetic acid, zinc and manganese may be separated in this manner.

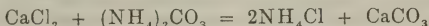
## Group V.

As a fresh solution of ammonium carbonate contains bicarbonate and carbamate, it is advisable to warm to 60-70°C. (but not above this temperature) to ensure the hydration of the carbamate :



and decomposition of the bicarbonate.

As the reaction :



is reversible, it is essential to use a large excess of ammonium carbonate and to warm only until the precipitate has become crystalline. In presence of much ammonium chloride, which is essential if magnesium is present, the precipitation of small amounts of calcium is incomplete, or may not take place at all. In case the presence of calcium has been indicated by the flame coloration test, but no precipitate is obtained with ammonium carbonate, a portion of the solution should be warmed and treated with ammonium oxalate, and any precipitate obtained examined for calcium by the flame coloration test.

Magnesium is frequently carried down in this group, and a careful reprecipitation must be carried out if traces of magnesium are to be detected in Group VI.

## Group VI.

In case the separation of aluminium, calcium, barium, etc., has not been complete, a *flocculent* precipitate may be obtained on addition of sodium phosphate. These metals may be removed completely from the filtrate from Group V by adding a large amount of ammonium chloride, and then ammonium sulphate and oxalate, and boiling for several minutes. On addition of sodium phosphate to the filtrate, the production of a *crystalline* precipitate indicates the presence of magnesium.

As traces of sodium and potassium salts will probably have been introduced with the group reagents, it is essential to confirm in the *original* substance, although it is to be remembered that other elements may be present in this which will mask the potassium flame coloration.

## EXAMINATION OF INSOLUBLE SUBSTANCES.

The substances which are insoluble or practically insoluble in single mineral acids, but are soluble in *aqua regia*, are : mercuric sulphide, antimony oxide, stannic sulphide, sulphur, and, after continued treatment, Prussian blue.

The substances which are insoluble or practically insoluble in mineral acids, including *aqua regia*, are : silver chloride, bromide, iodide and cyanide ; sulphates of barium, strontium and lead ; calcium fluoride ; fused lead chromate ; fused chromic oxide and chrome iron ore ; stannic and titanitic oxide ores ; alumina ; silica and many silicates ; carbon ; and carborundum. In addition, insoluble substances may contain combined phosphate, borate, sulphate, chloride or fluoride, which will not be found by the usual tests.

The general method of treatment is to fuse with fusion mixture, and extract the melt with hot water, and then with dilute acids.

Ignited ferric oxide, chromic oxide, and alumina, are very difficult to dissolve in acids, and are best fused with potassium bisulphate, or with acid potassium fluoride, a method of treatment which is the most satisfactory for the solution of many minerals.

Platinum vessels are attacked by easily reducible metals, such as lead, silver, and bismuth, and also by caustic alkalis. If porcelain vessels are used for the fusion, silica, alumina, etc., will be introduced. Consequently in presence of lead, etc., the acid fluoride method is used.

In case the insoluble substance has not already been examined by the dry-way tests, these tests should be carried out, as they generally give an indication of the substance under examination. According to the results obtained, one of the following methods is attempted for effecting solution if necessary for complete identification.

(1) Insoluble silver halides are dissolved by a solution of sodium thiosulphate, the solution darkening on heating. For complete identification, they are reduced in contact with zinc and dilute sulphuric acid to metallic silver. After filtering, the filtrate is tested for the halogen acid ; the residue is dissolved in dilute nitric acid, and hydrochloric acid added to test for silver.

(2) Insoluble barium, strontium, and calcium sulphates, silica and silicates should be fused with five times the amount of fusion mixture on platinum foil for several minutes, and the mass plunged into water whilst still hot.



After crushing with a glass rod and heating to the boiling-point, the liquid is filtered, and the residue washed with hot water and then treated with dilute hydrochloric acid. The aqueous and acid extracts are then examined for acid and metallic radicals respectively. The formation of a gelatinous precipitate on acidifying the aqueous solution indicates silica or silicate.

Sodium and potassium are detected in silicates after fusing with ammonium fluoride.

Silicon and ferro-silicon are dissolved by fusing with caustic soda.

An alternative method for insoluble sulphates is to confirm the sulphate by boiling with concentrated sodium carbonate solution, extract the residue with hydrochloric acid, and examine the solution for metallic radicals.

(3) Stannic and titanic oxide ores may be brought into solution by fusing with caustic soda in a silver or nickel dish. In the case of chrome iron ore, sodium peroxide should be added. The melt is extracted with water and the residue dissolved in hydrochloric acid.

Tin ores may be brought into solution by reducing to a fine powder, moistening with commercial hypophosphorous acid, and heating to dryness at a temperature not exceeding  $240^{\circ}\text{C}$ . The residue is extracted with hydrochloric acid, and tested for tin.

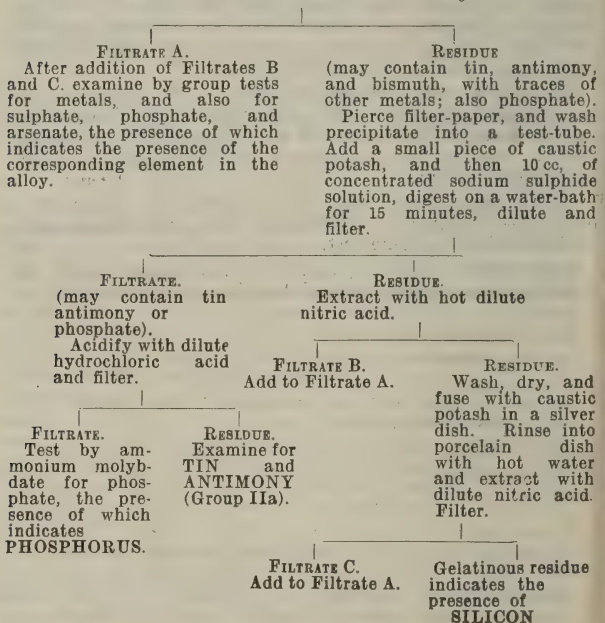
(4) Calcium fluoride may be identified by fusing with potassium bisulphate on platinum foil, and subsequently examining by the flame test.

(5) Insoluble complex cyanides are decomposed readily by digesting with caustic soda solution in a porcelain dish.

## EXAMINATION OF AN ALLOY.

As certain electronegative elements (*e.g.* carbon, silicon, phosphorus, and sulphur) are frequently present in small quantities, it is inadvisable to attempt to dissolve an alloy in hydrochloric acid, as volatile hydrides would be formed from carbides, silicides, phosphides, sulphides and arsenides, forms in which these electronegative elements are frequently present. It is hence convenient to dissolve in an oxidising agent, such as nitric acid. In the case of the ferro-alloys, a powdered sample may be fused with potassium bisulphate and persulphate.

Warm fragments of alloy with nitric acid (1 : 1). Dilute with twice the volume of water. A dark-coloured solution indicates the presence of *carbon*. Filter. If completely dissolved indicates absence of *tin* and *antimony*





## REACTIONS OF CERTAIN OF THE "RARER" METALS.

After dissolving the powdered substance by fusion with potassium bisulphate, with the addition of persulphate if necessary, and subsequently extracting with cold water and then with concentrated hydrochloric acid, the liquid is diluted and filtered. Any residue may then be dissolved by fusing with caustic soda and sodium peroxide in a nickel crucible, extracting with hot water, afterwards boiling the solution to destroy the last traces of sodium peroxide. The solution is acidified with hydrochloric acid; the formation of a precipitate indicates the presence of tungsten or silicon.

**-Preliminary test.** A small piece of zinc is introduced into a portion of the hydrochloric acid solution. After a brisk evolution of hydrogen has occurred for one minute, the liquid is decanted off the zinc, and, when quite free from undissolved zinc particles, two drops of a very dilute solution (N/1000) of methylene blue are added. The blue colour is destroyed in presence of traces of titanium, vanadium, molybdenum, and tungsten. In case the colour of the methylene blue persists, it may be taken as final evidence of the absence of these metals from the solution.

### Group I.

#### Tungsten.

The behaviour of a solution of an alkali tungstate is as follows :

(1) Mineral acids give a white precipitate which becomes yellow on heating. The white precipitate is soluble in phosphoric acid and in alkalies.

(2) Hydrogen sulphide does not give a precipitate in acid solution; but, on addition of ammonium sulphide and then an acid, a light brown precipitate soluble in ammonium sulphide is obtained.

(3) Reducing agents give a blue solution.

(4) Lead and mercurous tungstates are formed as white insoluble precipitates.

#### *Separation from Silicic Acid :*

Tungstic acid only is soluble in ammonium carbonate.

#### *Separation from Titanium :*

Tungstic acid only is insoluble in dilute sulphuric acid.

## Group IIa.

*Note.*—Although gold and platinum may be considered to belong to this Group, owing to the comparative difficulty with which their sulphides dissolve in yellow ammonium sulphide they are generally removed before proceeding to Group II. On heating with oxalic acid, gold is precipitated as such, and the platinum may be removed from the filtrate by evaporating with ammonium chloride to obtain the insoluble ammonium platinic chloride, and extracting the residue with alcohol (75 per cent.). The solution, freed from alcohol, is then used for Group II.

### Cold.

The behaviour of a solution of chlorauric acid is as follows :

(1) With cold solutions containing gold, hydrogen sulphide gives a black precipitate of the disulphide, soluble with difficulty in yellow ammonium sulphide, but more soluble in yellow potassium sulphide. At the boil, hydrogen sulphide gives a brown precipitate of metallic gold, soluble in alkali polysulphides.

(2) Ferrous salts and oxalic acid reduce acid solutions giving a brown precipitate of gold. (*Compare platinum.*)

(3) Stannous chloride gives a brown precipitate with strongly acid solutions, and a purple solution or precipitate with faintly acid solutions (also given by titanous chloride).

(4) Hydrogen peroxide precipitates finely divided gold from alkaline solutions.

### Platinum.

The behaviour of a solution of chlorplatinic acid is as follows :

(1) Hydrogen sulphide gives a dark-brown precipitate with hot solutions, soluble with difficulty in alkali polysulphides.

(2) Ammonium and potassium chloride give yellow, crystalline precipitates with concentrated solutions, or on addition of alcohol in the case of dilute solutions.

(3) Alkali iodides give dark-brown solutions

(4) Neither ferrous salts nor oxalic acid precipitate platinum from acid solutions. (*Compare gold.*)

(5) Stannous chloride gives a blood-red solution, the colour being extracted by ether.

## Molybdenum

The behaviour of a solution of an alkali molybdate is as follows :

(1) Hydrogen sulphide gives a blue solution and then a brown precipitate soluble in ammonium sulphide. On oxidation in air or by concentrated nitric acid, the brown sulphide gives glistening needles of molybdic oxide, which is yellow whilst hot.

(2) On heating with several drops of concentrated sulphuric acid in a porcelain dish, and allowing to cool, an intense blue mass is formed.

(3) Reducing agents give a blue solution, which on further reduction with zinc and concentrated hydrochloric acid, becomes successively green, orange, and pink.

(4) Addition of potassium ferrocyanide to a solution containing a mineral acid gives a reddish-brown precipitate soluble in caustic alkalies and in ammonia. (*Compare uranium.*)

### *Separation from Arsenic, Antimony and Tin :*

Fuse Group IIa precipitate with twenty times the amount of a mixture of equal parts of fusion mixture and sodium peroxide in a nickel crucible for ten minutes. Extract the sodium arsenate and molybdate with cold water, filter from the undissolved sodium antimonate and stannic oxide, and wash with caustic soda solution.

Acidify the filtrate with hydrochloric acid, make strongly ammoniacal, and precipitate the arsenate by addition of magnesia mixture. Examine concentrated filtrate for molybdenum.

The residue is dissolved in hydrochloric acid (1 : 1) and examined for antimony and tin as usual.

## Group III.

### Titanium.

The behaviour of a solution of a titanic salt is as follows :

(1) Ammonia and ammonium sulphide give a white, gelatinous precipitate.

(2) Caustic potash gives a white, gelatinous precipitate, insoluble in excess. (*Compare aluminium.*)

(3) Tin and zinc, but not hydrogen sulphide or sulphur dioxide (*compare vanadium*), reduce acid solutions to violet titanous salts.

(4) With hydrogen peroxide, titanium sulphate gives a colour similar to that of vanadium (3).

(5) Potassium ferrocyanide gives a brown precipitate from slightly acid solutions.

*Separation from Iron, Aluminium and Chromium.*

Add sodium carbonate to the cold solution (free from organic acids) until a slight precipitate is obtained. After dissolving precipitate in a few drops of sulphuric acid, dilute to a large volume with water, to hydrolyse the sulphate, and boil for half an hour. Filter, and wash the precipitated metatitanic acid with very dilute sulphuric acid. The precipitate dissolves slowly on digesting with concentrated hydrochloric acid.

### Uranium.

The behaviour of a yellowish-green solution of a uranyl salt is as follows :

(1) Ammonia and caustic alkalies give a yellow, amorphous precipitate of a uranate, soluble in alkali carbonates, particularly in ammonium carbonate.

(2) Ammonium sulphide gives a brownish-red precipitate, soluble in dilute acids and in ammonium carbonate.

(3) Potassium ferrocyanide yields a brown precipitate, insoluble in mineral acids, which is turned yellow by caustic potash. (*Compare molybdenum.*)

*Separation from Iron, Aluminium and Chromium.*

Dissolve Group III precipitate in a small amount of dilute hydrochloric acid, make strongly alkaline with caustic soda, boil, dilute with hot water, and boil for several minutes. Filter hot from sodium aluminate solution, wash precipitate thoroughly with hot water. Warm precipitate with ammonium carbonate solution, but do not boil. Filter, and test for uranium in filtrate by acidifying and adding potassium ferrocyanide.

### Group IV.

#### Vanadium.\*

The behaviour of a solution of an alkali vanadate is as follows :

(1) Ammonium sulphide gives a red solution which on acidifying with dilute sulphuric acid gives a brown precipitate soluble in alkalies, and alkali carbonates and sulphides.

\* Although vanadate solutions do not give a precipitate with ammonium sulphide, which first acts as a reducing agent, it is convenient to consider vanadium in Group IV.

(2) Hydrogen sulphide, sulphur dioxide, and other reducing agents give blue solutions.

(3) Hydrogen peroxide produces a reddish brown solution, the colour of which is not extracted by ether. (*Compare chromate.*)

(4) Lead and mercurous vanadates are insoluble in water but soluble in nitric acid.

#### *Detection of Vanadium in Ores, etc.*

Fuse with five times the weight of a mixture containing four parts of fusion mixture and one part of potassium nitrate. Extract with water and reduce any manganate formed with alcohol. Filter, and almost neutralise filtrate with nitric acid. Evaporate the alkaline solution almost to dryness, add water, and filter. Add mercurous nitrate solution, when any phosphate, arsenate, chromate, molybdate, tungstate, or vanadate present will be precipitated. Boil, filter, and dry precipitate. Ignite, fuse the residue with a small amount of sodium carbonate, and extract with water. Yellow solution indicates *chromium*. Acidify with sulphuric acid, and precipitate *arsenic* and *molybdenum* by means of hydrogen sulphide. Filter, and pass a current of carbon dioxide through filtrate at the boil. Test for *vanadium* in filtrate by Test (3) above.

### Group VI.

#### **Lithium.**

(1) Neither chlorplatinic acid nor tartaric acid gives a precipitate. (*Compare potassium.*)

(2) On digesting in concentrated solution with sodium phosphate, a white precipitate of trilithium phosphate is obtained, which is fusible (distinction from magnesium and alkaline earth metals).

(3) On warming with ammonium carbonate and ammonia, concentrated solutions give a white precipitate of the slightly soluble carbonate. (*Compare alkali carbonates.*) In presence of large amounts of alkali chlorides or ammonium chloride, no precipitate is obtained.

#### *Separation from Sodium and Potassium.*

Of the anhydrous chlorides, only the lithium salt is soluble in ether-alcohol mixture and in amyl alcohol.

## REAGENTS.

## CONCENTRATED ACIDS AND ALKALIES.

|                                 |     |     |     |       |
|---------------------------------|-----|-----|-----|-------|
| Hydrochloric acid, Sp. Gr. 1.19 | ... | ... | ... | 38%   |
| Nitric acid, Sp. Gr. 1.40       | ... | ... | ... | 65%   |
| Sp. Gr. 1.20                    | ... | ... | ... | 32.5% |
| Sulphuric acid, Sp. Gr. 1.84    | ... | ... | ... | 96%   |
| Acetic acid, Freezing pt. 7°C.  | ... | ... | ... | 93%   |
| glacial, Freezing pt. 17°C.     | ... | ... | ... | 98%   |
| Ammonia, Sp. Gr. 0.880          | ... | ... | ... | 35%   |
| Sp. Gr. 0.905                   | ... | ... | ... | 27%   |

## SATURATED SOLUTIONS.

At 15° C. 100 gramm. of solution contain :

|                           |     |             |  |
|---------------------------|-----|-------------|--|
| Chlorine water            | ... | ...         | 0.73 gramm. Cl.                        |
| Bromine water             | ... | ...         | 3.66 gramm. Br.                        |
| Hydrogen sulphide water   | ... | ...         | 0.48 gramm. H <sub>2</sub> S.          |
| Baryta water              | ... | 5.95 gramm. | Ba(OH) <sub>2</sub> .8H <sub>2</sub> O |
| Lime water                | ... | ...         | 0.17 gramm. Ca(OH) <sub>2</sub> .      |
| Calcium sulphate solution | ... | ...         | 0.21 gramm. CaSO <sub>4</sub> .        |

## SPECIAL REAGENTS.

*Ammonium molybdate solution.* 150 gramm. of ammonium molybdate [(NH<sub>4</sub>)<sub>6</sub>Mo<sub>7</sub>O<sub>24</sub>.4H<sub>2</sub>O] are dissolved in a litre of water, and the solution poured into a litre of nitric acid (Sp. Gr. 1.2).

As a test for phosphate and arsenate, the reagent must be used in large excess, and the test is more delicate in presence of an equal volume of a concentrated solution of ammonium nitrate. In the case of arsenate the precipitate only forms rapidly on heating.

The yellow precipitate is the insoluble ammonium (or potassium) salt of phospho- or arseno-molybdic acid, which is soluble. The ammonium salt dissolves in alkalies, and addition of magnesium chloride to the solution gives a white crystalline precipitate of magnesium ammonium phosphate or arsenate.

*Ammonium sulphide.* Hydrogen sulphide is passed through 3 parts of ammonia solution until saturated, and 2 parts of the same ammonia solution are added. Yellow ammonium sulphide is prepared by digesting this solution with powdered (roll) sulphur.



*Aqua regia.* 1 volume of concentrated nitric acid mixed with 4 volumes of concentrated hydrochloric acid.

*Cobalt reagent.*  $\alpha$ -Nitroso- $\beta$ -naphthol is used in the form of its sodium salt, obtained by dissolving 0.1 grm. in 2 cc. of 2N caustic soda diluted to one litre.

*Fehling's solution.*

A. 34.6 grm. of  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  in 500 cc. of water.

B. 173 grm. of Rochelle salt and 65 grm. of caustic soda in 500 cc. of water.

Equal volumes are mixed just before use.

*Fusion mixture* (for dry-way tests). Equi-molecular proportions of dry sodium carbonate and potassium carbonate.

*Hydrofluosilicic acid.* Mixture of 1 part of calcium fluoride, 1 part of sand, and 6 parts of sulphuric acid is distilled, the leading tube dipping under mercury, on top of which is a layer of water. The solution is decanted and filtered.

*Hydrogen peroxide.* 2 per cent. solution (ten volumes of available oxygen).

*Magnesia mixture.* 100 grm. of  $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$  are dissolved in a litre of water, 250 grm. of ammonium chloride, and then 300 grm. ammonia (Sp. Gr. 0.880) added. After allowing to stand for several days the clear liquid is used.

*Nessler solution.* 35 grm. of potassium iodide and 12.5 grm. of mercuric chloride are dissolved in about 800 cc. of water. 120 grm. of caustic soda are dissolved in this, and the solution allowed to cool. Saturated mercuric chloride solution is then added drop by drop with constant stirring until a slight red precipitate remains. The solution is diluted to a litre, the precipitate allowed to settle, and the clear liquor siphoned off, and preserved in the dark.

The intensely coloured compound found in presence of ammonia is dimercuriammonium iodide,  $\text{NHg}_2\text{I}$ .

*Nickel reagents:*

*Dimethylglyoxime* is used in 1 per cent. alcoholic solution, or in saturated aqueous solution, in which case the mixture must be allowed to stand to obtain the pink precipitate.

*$\alpha$ -Benzildioxime* is more easily prepared and is more delicate as a reagent for nickel. It is obtained by digesting an alcoholic solution of benzil with an equal weight of hydroxylamine hydrochloride. The precipitate obtained is washed twice with 50 per cent. alcohol. For qualitative purposes it is conveniently used in the form of the sodium salt, prepared by dissolving 0.1 grm. of the compound in

5 cc. of 2N caustic soda diluted to one litre. One cc. of this reagent is added to the solution under examination, which should contain ammonia and ammonium chloride.

*Nitrite reagent* (Ilosvay). See Nitrites, p. 35.

*Nitrate reagent* (Diphenylamine test). See Nitrates, p. 34.

*Sodium cobaltinitrite* A fresh 1 per cent. solution is used, and gives the yellow, crystalline  $K_2Na[Co(NO_2)_6] \cdot H_2O$  in neutral or acetic acid solution.

*Starch solution.* The starch is ground with water to a thin cream, which is poured into sufficient boiling water to produce a 1 per cent. solution. The cold, clear solution is decanted for use. (After keeping for some time, the colour obtained with iodine is not so intense as with a fresh solution; it may, however, be preserved for a longer period by the addition of several drops of chloroform.)

## IMPURITIES IN REAGENTS.

In the following notes, the more probable impurities which may be present in stated reagents are given.

Before testing for impurities, reagents must be diluted if necessary to a suitable concentration. Only tests of a special character have been inserted. Tests of a general character are :

- (1) Volatile substances should leave no residue.
- (2) Acid or alkaline reaction of a solid, which should give a clear solution if soluble in water.
- (3) Test for heavy metals by means of ammonium sulphide.

As the testing of reagents is largely a matter of testing for *traces* of impurities, tests should be allowed to stand for several hours.

*Acetic acid.* Test for common mineral acids, and for copper, lead, iron, and calcium, also for sulphite.

After mixing the dilute acid (1 : 3) with twice its volume of N/100 permanganate, the colour should remain after standing fifteen minutes.

*Ammonia.* Test for chloride and sulphate. Also for carbonate by warming with lime water, and for pyridine, etc., by almost neutralising the dilute solution (1 : 3) with dilute sulphuric acid, using methyl orange as indicator, when the liquid obtained should be odourless. The concentrated



solution should not give a yellow or pink coloration on acidifying with nitric acid (1 : 1).

*Ammonium carbonate.* Test for chloride, iodide, sulphate, and thiocyanate. Test for organic matter by evaporating with excess of nitric acid; the residue should be white.

*Ammonium chloride.* Test for sulphate, phosphate, thiocyanate, and organic matter (see *ammonium carbonate*).

A 5 per cent. solution should be neutral (even the purest commercial samples are acid, and contain traces of iron).

*Ammonium fluoride.* Test for chloride and sulphate. Acidity indicates presence of bifluoride. Lead generally present. On volatilisation, 10 grm. should give only 2-3 mgm. residue.

*Ammonium nitrate.* See *ammonium chloride*. Test for nitrite.

*Ammonium oxalate.* Test for chloride, sulphate, free ammonia, free oxalic acid, and for potassium.

*Ammonium sulphate.* Test for chloride, nitrate, phosphate, thiocyanate, and arsenic.

*Ammonium sulphide solution.* Test for carbonate by warming with lime water, for free ammonia by warming with magnesium chloride, and for arsenic.

*Ammonium thiocyanate.* Test for chloride and sulphate. 1 grm. should dissolve completely in 10 cc. of alcohol. A 5 per cent. solution should remain colourless after addition of dilute hydrochloric acid. It is essential that the sample should be pure white, as yellowish samples contain organic matter. Traces of lead and iron, and of sulphuric acid are frequently present in commercial samples.

*Barium carbonate.* The filtrate obtained by adding sulphuric acid to a hydrochloric acid solution should not leave any residue on evaporation and ignition.

*Barium chloride.* Test for chlorate by warming 2 grm. with 10 cc. of concentrated hydrochloric acid. Commercial samples frequently contain traces of iron and potassium, and are moist, due to the presence of calcium chloride.

*Barium hydroxide.* Test for chloride. Commercial samples contain sulphate, sulphite, sulphide, and thio-sulphate. Sample should be completely soluble in water, or leave only a slight residue of barium carbonate.

*Barium nitrate.* Test for chloride and for lead.

*Bromine.* Test for chlorine, iodine, sulphur and organic compounds (bromoform, etc.), as follows: Convert several grams into ammonium bromide by adding water and then slowly adding an excess of ammonia. A residue of oily drops indicates the presence of organic compounds. Traces

of iodide are detected by adding ferric chloride and chloroform. Traces of chloride are detected by using the fact that silver chloride is soluble in warm ammonium sesquicarbonate solution (1 part of ammonium carbonate, 1 part of ammonia, Sp. Gr. 0.96, and 3 parts of water) whereas the bromide is practically insoluble, and the iodide is quite insoluble.

*Calcium chloride.* Test for nitrate, sulphate, ammonium compounds, and iron. 1 grm. should dissolve completely in 10 cc. of alcohol. A 5 per cent. solution should remain clear on standing with calcium sulphate solution.

*Calcium oxide.* Test for chloride, sulphate, carbonate, silica, alumina and iron.

*Copper sulphate.* Test for iron and zinc.

*Ferric chloride.* Test for free hydrochloric acid, by bringing the stopper of an ammonia bottle near to the solid. Also for free chlorine with starch-iodide paper, and for arsenic, copper, zinc, ferrous chloride, sulphates and nitrates. Sample should be completely soluble in ether.

*Hydrochloric acid.* Test for sulphate, sulphurous acid, free chlorine, other halogen acids, and for iron, arsenic, aluminium, and calcium.

*Hydrogen peroxide.* Test for chloride, fluoride, hydrofluosilicate, sulphate, phosphate, alumina, magnesia, and free acid.

*Iodine.* Add ammonia to the aqueous extract and test for chloride and bromide. Test another aqueous extract for cyanogen by adding sodium thiosulphate until decolorised, then a crystal of ferrous sulphate, a drop of ferric chloride solution, and several drops of caustic soda; warm the solution and acidify with hydrochloric acid, when no blue colour should be developed.

*Lead acetate.* Test for chloride, nitrate, alkaline earth metals, copper, and iron.

*Nickel salts.* Test for aluminium and cobalt.

*Nitric acid.* Test for sulphuric acid in the residue obtained by evaporating 10 cc. to 0.5 cc.; for hydrochloric acid by adding 10 cc. to 50 cc. of water containing several drops of silver nitrate solution; for iodine compounds (iodic acid, etc.) by diluting with an equal volume of water, adding a piece of zinc and then carbon disulphide to extract any iodine liberated; also test for iron and arsenic.

*Oxalic acid.* Test for sulphate, ammonia, sodium, potassium, calcium, and iron. The crystals should not have effloresced.

*Phosphoric acid.* Test for nitric acid, halogen acids, sulphuric acid, metaphosphoric acid, ammonia, and arsenic.

On boiling 5 cc. with 5 cc. of sulphuric acid and 5 drops of potassium permanganate (0.1 per cent.), the red colour should persist after five minutes, indicating the absence of lower phosphorus acids and of organic matter.

*Potassium bisulphate.* Test for chloride, nitrate, and arsenic.

*Potassium carbonate.* Test for chloride, chlorate, nitrate, sulphate, phosphate, silicate, cyanide, sulphide, sodium and aluminium.

*Potassium chlorate.* Test for chloride, nitrate, sulphate, sodium, calcium, lead, and arsenic.

*Potassium chloride.* Test for sulphate, calcium, and manganese

*Potassium chromate.* Test for chloride, sulphate, aluminium and calcium. Phenolphthalein should not give a red colour with a 0.5 per cent. solution.

*Potassium cyanide.* Test for chloride, sulphate, cyanate, thiocyanate, and ferrocyanide, and for sodium.

*Potassium dichromate.* Test for sulphate, chloride, calcium and aluminium.

*Potassium ferrocyanide.* Test for chloride, sulphate, and sodium.

*Potassium hydroxide.* Test for chloride, nitrate, nitrite, carbonate, sulphate, phosphate, silicate, sulphide, calcium and aluminium.

*Potassium iodide.* Test for carbonate (by alkalinity to litmus paper), chloride and bromide, iodate, nitrate, sulphate, sulphite and cyanide.

*Potassium nitrate.* Test for chloride, chlorate, perchlorate, sulphate, calcium, and sodium.

*Potassium nitrite.* Test for free alkali, carbonate, chloride, nitrate, sulphate, and lead.

*Potassium permanganate.* Test for chloride and sulphate after boiling a solution with alcohol, and for nitrate after decolorising with oxalic acid.

*Sodium acetate.* Test for common mineral acids.

*Sodium carbonate.* Test for chloride, sulphate, thio-sulphate, phosphate, silicate, ammonia, iron, arsenic, calcium, and potassium.

*Sodium chloride.* Test for sulphate, iodide (by ferric chloride and starch), ammonia, calcium, magnesium, and potassium.

*Sodium hydroxide.* Test for chloride, nitrate, carbonate, sulphate, phosphate, borate, silicate, ammonia, aluminium, iron, calcium, and potassium.

*Sodium nitrite.* See *potassium nitrite*, also test for potassium by means of sodium cobaltinitrite

*Sodium phosphate.* Test for chloride, nitrate, carbonate, sulphate, arsenic, potassium, and calcium.

## Table of the Limits of Lead and Arsenic

allowed in the Drugs of the British Pharmacopœia, 1914.

Strictly speaking, the British Pharmacopœia is not a legal standard, but it is a presumptive one for the articles and preparations named in it. Details for applying the tests for lead and arsenic are given in Appendices V and VI of the B.P. The last edition (1914) now uses the terms "purified alum" and "purified borax" to distinguish the medicinal from the commercial varieties. It also includes glucose, but in view of the "salts of tartar" litigation during 1914 the synonym "salts of tartar" for potassium carbonate has been omitted:

|  | Parts per Million. |     |
|--|--------------------|-----|
|  | Pb.                | As. |
| Acid, acetic (33% $\text{CH}_3\text{COOH}$ ) .. .. .                   | -                  | 2   |
| „ acetylsalicylic .. .. .  | 10                 | 2   |
| „ benzoic .. .. .  | -                  | 2   |
| „ boric .. .. .  | 25                 | 5   |
| „ citric .. .. .   | 20                 | 1.4 |
| „ hydriodic dilute (10% $\text{HI}$ ) .. .. .                          | 10                 | 5   |
| „ hydrobromic dilute (10% $\text{HBr}$ ) .. .. .                       | 5                  | 5   |
| „ hydrochloric (31.79% $\text{HCl}$ ) .. .. .                          | 10                 | 5   |
| „ lactic (75% lactone, 10% acid) .. .. .                               | 10                 | 5   |
| „ nitric (70% $\text{HNO}_3$ Sp. Gr. 1.42) .. .. .                     | 20                 | 5   |
| „ phosphoric conc. (Sp. Gr. 1.5) 66.3% $\text{H}_3\text{PO}_4$ .. .. . | 10                 | 5   |
| „ salicylic .. .. .  | -                  | 2   |
| „ sulphuric (Sp. Gr. 1.841) 95% $\text{H}_2\text{SO}_4$ .. .. .        | 20                 | 5   |
| „ sulphurous (5% $\text{SO}_2$ ) .. .. .                               | 10                 | 5   |
| „ tartaric .. .. .   | 20                 | 1.4 |
| Alum, purified ( $\text{NH}_4$ or K) .. .. .                           | 0                  | 5   |
| Ammonia solution, strong (Sp. Gr. 0.888) .. .. .                       | -                  | 0.5 |
| Ammonium benzoate .. .. .  | 10                 | 2   |
| „ bromide .. .. .  | 10                 | 5   |
| „ carbonate .. .. .  | 5                  | 2   |
| „ chloride .. .. .   | 5                  | 5   |

## Parts per Million

|   | Pb. | As.  |
|---|-----|------|
| Antimony, sulphuretted .. .. .                | -   | 1000 |
| Bismuth carbonate .. .. .                     | -   |      |
| " salicylate .. .. .                          | -   | 2    |
| " subnitrate .. .. .                          | -   | 2    |
| Borax, purified .. .. .                       | 5   | 5    |
| Calcium carbonate pptd. .. .. .               | 10  | 5    |
| " chloride .. .. .                            | 20  | 5    |
| " hydroxide .. .. .                           | 20  | 5    |
| " hypophosphite .. .. .                       | 10  | 5    |
| " lactate .. .. .                             | 10  | 5    |
| " oxide .. .. .                               | -   | 5    |
| " phosphate .. .. .                           | -   | 5    |
| Chalk, prepared .. .. .                       | -   | 5    |
| Copper sulphate .. .. .                       | -   | 10   |
| Ferric chloride solution, strong .. .. .      | -   | 10   |
| " sulphate solution .. .. .                   | -   | 5    |
| Ferrous sulphate .. .. .                      | -   | 2    |
| " " exsiccated (77% $\text{FeSO}_4$ ) .. .. . | -   | 5    |
| " carbonate, saccharated .. .. .              | -   | 5    |
| Glucose .. .. .                               | -   | 2    |
| Glycerin .. .. .                              | -   | 4    |
| Iron (wire or nails) .. .. .                  | -   | 200  |
| " reduced .. .. .                             | -   | 200  |
| " ammonium citrate .. .. .                    | -   | 5    |
| " potassium tartrate .. .. .                  | -   | 5    |
| " and quinine citrate .. .. .                 | -   | 5    |
| Lithium carbonate .. .. .                     | 10  | 5    |
| " citrate .. .. .                             | 5   | 2    |
| Magnesium bicarbonate solution .. .. .        | 0.5 | 0.2  |
| " carbonate .. .. .                           | 20  | 5    |
| " oxide .. .. .                               | 20  | 5    |
| " sulphate .. .. .                            | 5   | 5    |
| Potassium acetate .. .. .                     | 10  | 5    |
| " bicarbonate .. .. .                         | 5   | 5    |
| Potassium bromide .. .. .                     | 10  | 5    |
| " carbonate .. .. .                           | 5   | 2    |
| " chlorate .. .. .                            | 10  | 5    |
| " citrate .. .. .                             | 10  | 2    |
| " iodide .. .. .                              | 10  | 5    |
| " nitrate .. .. .                             | 10  | 5    |
| " sulphate .. .. .                            | 20  | 5    |
| " tartrate .. .. .                            | 20  | 2    |
| " " acid .. .. .                              | 20  | 2    |



### Table of the Limits of Impurities

allowed in the Drugs of the United States Pharmacopœia,  
9th Revision, 1916.

The U.S. Pharmacopœia and the National Formulary are the standards for drugs under the Pure Food and Drugs Act of June 30, 1906. "Standards of purity and strength, prescribed in the text of this Pharmacopœia, are intended solely to apply to substances which are used for medicinal purposes or in determining the identity or purity of such substances."

The following U.S.P. drugs are required to be free from arsenic (indicated by \*) and/or heavy metals (lead, copper, etc., indicated by †), within the limits of the tests for impurities given in U.S.P., Part II, p. 584:—

[illegible]



|                                 |         |     |
|---------------------------------|---------|-----|
| Caffeine citrate                | .. .. . | †   |
| Caffeine-sodium benzoate        | .. .. . | †   |
| Calcium bromide                 | .. .. . | †   |
| Calcium carbonate, precipitated | .. .. . | †   |
| Calcium chloride                | .. .. . | †   |
| Calcium glycono-phosphate       | .. .. . | †   |
| Calcium hypophosphite           | .. .. . | * † |
| Calcium lactate                 | .. .. . | †   |
| Cerium oxalate                  | .. .. . | * † |
| Copper sulphate                 | .. .. . | †   |
| Ferrous sulphate                | .. .. . | †   |
| Gelatin                         | .. .. . | †   |
| Glucose                         | .. .. . | * † |
| Glycerin                        | .. .. . | * † |
| Hydrogen peroxide (3%)          | .. .. . | * † |
| Iron, reduced                   | .. .. . | *   |
| Lactose                         | .. .. . | †   |
| Lithium bromide                 | .. .. . | †   |
| Lithium carbonate               | .. .. . | †   |
| Lithium citrate                 | .. .. . | †   |
| Magnesium carbonate             | .. .. . | †   |
| Magnesium oxide                 | .. .. . | †   |
| Magnesium sulphate              | .. .. . | * † |
| Methyl salicylate               | .. .. . | †   |
| Methyl-thionine chloride        | .. .. . | *   |
| Oil of anise                    | .. .. . | †   |
| Oil of bitter almond            | .. .. . | †   |
| Oil of cinnamon                 | .. .. . | †   |
| Phenol-phthalein                | .. .. . | †   |
| Potassium acetate               | .. .. . | * † |
| Potassium bicarbonate           | .. .. . | †   |
| Potassium bitartrate            | .. .. . | †   |
| Potassium bromide               | .. .. . | †   |
| Potassium carbonate             | .. .. . | †   |
| Potassium chlorate              | .. .. . | †   |
| Potassium citrate               | .. .. . | * † |
| Potassium-sodium tartrate       | .. .. . | †   |
| Potassium hydroxide             | .. .. . | †   |
| Potassium hypophosphite         | .. .. . | *   |
| Potassium iodide                | .. .. . | †   |
| Potassium nitrate               | .. .. . | †   |
| Salicin                         | .. .. . | †   |
| Sodium acetate                  | .. .. . | * † |
| Sodium arsenate                 | .. .. . | †   |
| Sodium benzoate                 | .. .. . | †   |
| Sodium bicarbonate              | .. .. . | †   |



|                                |         |     |
|--------------------------------|---------|-----|
| Sodium borate                  | .. .. . | * † |
| Sodium bromide                 | .. .. . | †   |
| Sodium cacodylate              | .. .. . | †   |
| Sodium carbonate, monohydrated | .. .. . | †   |
| Sodium chloride                | .. .. . | †   |
| Sodium citrate                 | .. .. . | * † |
| Sodium glycono-phosphate       | .. .. . | †   |
| Sodium hydroxide               | .. .. . | †   |
| Sodium hypophosphite           | .. .. . | * † |
| Sodium iodide                  | .. .. . | †   |
| Sodium nitrite                 | .. .. . | †   |
| Sodium perborate               | .. .. . | †   |
| Sodium phenol-sulphonate       | .. .. . | †   |
| Sodium phosphate, dibasic      | .. .. . | * † |
| Sodium salicylate              | .. .. . | †   |
| Sodium sulphate                | .. .. . | * † |
| Sodium sulphite, exsiccated    | .. .. . | * † |
| Sodium thiosulphate            | .. .. . | * † |
| Strontium bromide              | .. .. . | †   |
| Strontium iodide               | .. .. . | †   |
| Strontium salicylate           | .. .. . | †   |
| Sulphur                        | .. .. . | *   |
| Uranium nitrate                | .. .. . | †   |
| Zinc acetate                   | .. .. . | * † |
| Zinc carbonate, precipitated   | .. .. . | †   |
| Zinc chloride                  | .. .. . | †   |
| Zinc oxide                     | .. .. . | †   |
| Zinc phenol-sulphonate         | .. .. . | * † |
| Zinc sulphate                  | .. .. . | * † |
| Zinc valerate                  | .. .. . | * † |

# VOLUMETRIC ANALYSIS.

## STANDARD SOLUTIONS.

The term *normal* (N) is used to indicate a solution of which one litre contains the gram-equivalent of the dissolved substance. *Seminormal* (N/2), *decinormal* (N/10), *centinormal* (N/100), etc., solutions contain 1/2, 1/10, 1/100, etc., of the gram-equivalent per litre. For example, as hydrochloric acid is a monobasic acid, a normal solution contains 36.47 gm. per litre ( $\text{HCl}=36.47$ ), whereas a normal solution of sulphuric acid, a dibasic acid, contains  $98.08/2=49.04$  gm. per litre ( $\text{H}_2\text{SO}_4=98.08$ ).

Similarly normal caustic soda contains 40.01 gm. per litre ( $\text{NaOH}=40.01$ ), whereas normal sodium carbonate contains  $106.00/2=53.00$  gm. per litre ( $\text{Na}_2\text{CO}_3=106.00$ ).

*Correction of Burette Readings to 15°C.* (Schlösser).

| °C. | Correction in cc. for 1 litre of |                               |                      |  |            |                                |                |
|-----|----------------------------------|-------------------------------|----------------------|--|------------|--------------------------------|----------------|
|     | N.<br>HCl                        | N.<br>$\text{H}_2\text{SO}_4$ | N.<br>$\text{HNO}_3$ | N.<br>$\text{H}_2\text{C}_2\text{O}_4$ | N.<br>NaOH | N.<br>$\text{Na}_2\text{CO}_3$ | N/10<br>solns. |
| 5   | +1.26                            | +1.94                         | +2.00                | +1.33                                  | +2.18      | +2.03                          | +0.60          |
| 6   | 1.18                             | 1.79                          | 1.94                 | 1.25                                   | 1.99       | 1.87                           | 0.60           |
| 7   | 1.10                             | 1.63                          | 1.68                 | 1.16                                   | 1.80       | 1.69                           | 0.59           |
| 8   | 1.00                             | 1.46                          | 1.50                 | 1.04                                   | 1.60       | 1.50                           | 0.56           |
| 9   | 0.88                             | 1.28                          | 1.31                 | 0.94                                   | 1.39       | 1.31                           | 0.52           |
| 10  | 0.76                             | 1.09                          | 1.11                 | 0.81                                   | 1.18       | 1.11                           | 0.46           |
| 11  | 0.63                             | 0.89                          | 0.91                 | 0.67                                   | 0.96       | 0.90                           | 0.40           |
| 12  | 0.48                             | 0.68                          | 0.69                 | 0.52                                   | 0.73       | 0.69                           | 0.32           |
| 13  | 0.33                             | 0.46                          | 0.46                 | 0.35                                   | 0.50       | 0.47                           | 0.22           |
| 14  | 0.17                             | 0.23                          | 0.23                 | 0.18                                   | 0.25       | 0.24                           | 0.12           |
| 15  | 0.0                              | 0.00                          | 0.00                 | 0.00                                   | 0.00       | 0.00                           | 0.00           |
| 16  | -0.18                            | -0.24                         | -0.25                | -0.20                                  | -0.25      | -0.24                          | -0.13          |
| 17  | 0.36                             | 0.49                          | 0.50                 | 0.40                                   | 0.51       | 0.49                           | 0.27           |
| 18  | 0.56                             | 0.75                          | 0.76                 | 0.61                                   | 0.78       | 0.75                           | 0.42           |
| 19  | 0.76                             | 1.02                          | 1.03                 | 0.82                                   | 1.05       | 1.02                           | 0.59           |
| 20  | 0.97                             | 1.30                          | 1.30                 | 1.05                                   | 1.33       | 1.29                           | 0.76           |
| 21  | 1.19                             | 1.58                          | 1.58                 | 1.29                                   | 1.62       | 1.57                           | 0.95           |
| 22  | 1.41                             | 1.86                          | 1.87                 | 1.54                                   | 1.92       | 1.85                           | 1.14           |
| 23  | 1.64                             | 2.15                          | 2.17                 | 1.80                                   | 2.23       | 2.14                           | 1.35           |
| 24  | 1.88                             | 2.45                          | 2.47                 | 2.07                                   | 2.54       | 2.44                           | 1.56           |
| 25  | 2.14                             | 2.76                          | 2.78                 | 2.34                                   | 2.85       | 2.75                           | 1.79           |
| 26  | 2.40                             | 3.08                          | 3.10                 | 2.62                                   | 3.17       | 3.06                           | 2.02           |
| 27  | 2.67                             | 3.41                          | 3.43                 | 2.90                                   | 3.50       | 3.38                           | 2.27           |
| 28  | 2.95                             | 3.75                          | 3.76                 | 3.19                                   | 3.83       | 3.70                           | 2.52           |
| 29  | 3.23                             | 4.09                          | 4.10                 | 3.49                                   | 4.17       | 4.04                           | 2.78           |
| 30  | 3.52                             | 4.43                          | 4.44                 | 3.82                                   | 4.52       | 4.38                           | 3.06           |

# STANDARD SOLUTIONS OF ACIDS, ALKALIES AND SALTS.

*NOTE.*—The formulæ given represent the commercial form of the salt; the figures, the number of grams of solid (including water of crystallisation, if definite) contained in a litre of the NORMAL solution; and the NORMALITY of the solution suggested for general use in the laboratory is given in brackets.

|   |                |        |
|---|----------------|--------|
| Acetic acid   | 60.04          | (2N)   |
| Ammonia   | 17.03          | (2N)   |
| Ammonium carbonate  | (20% solution) |        |
| Ammonium chloride, $\text{NH}_4\text{Cl}$   | 53.50          | (2N)   |
| Ammonium oxalate, $(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$      | 71.06          | (N/2)  |
| Ammonium sulphate   | 66.07          | (N)    |
| Arsenious oxide, $\text{As}_2\text{O}_3$  | 49.48          |        |
| Barium chloride, $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$                            | 122.16         | (N)    |
| Calcium chloride, $\text{CaCl}_2 + x \text{ aq.}$                                     | 55.50          | (N)    |
| Caustic potash  | 56.11          | (2N)   |
| Caustic soda  | 40.01          | (2N)   |
| Cobalt nitrate, $\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$                  | 145.54         | (N)    |
| Copper sulphate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$                            | 124.85         | (N/2)  |
| Ferric chloride, $\text{FeCl}_3 + x \text{ aq.}$                                      | 54.08          | (N)    |
| Hydrochloric acid   | 36.47          | (2N)   |
| Lead acetate, $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 3\text{H}_2\text{O}$ | 189.66         | (N)    |
| Magnesium sulphate, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$                         | 123.24         | (N)    |
| Mercuric chloride, $\text{HgCl}_2$  | 135.76         | (N/2)  |
| Mercurous nitrate, $\text{Hg}_2(\text{NO}_3)_2$                                       | 262.3          | (N)    |
| Nitric acid   | 63.02          | (2N)   |
| Oxalic acid, $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$               | 63.03          |        |
| Potassium dichromate, $\text{K}_2\text{Cr}_2\text{O}_7$                               | 49.03          | (N)    |
| Potassium ferrocyanide, $\text{K}_4\text{Fe}(\text{CN})_6 \cdot 3\text{H}_2\text{O}$  | 105.62         | (N)    |
| Potassium iodide, $\text{KI}$   | 166.02         | (N/2)  |
| Potassium permanganate, $\text{KMnO}_4$   | 31.61          | (N)    |
| Potassium thiocyanate, $\text{KCNS}$  | 97.18          | (N/2)  |
| Silver nitrate, $\text{AgNO}_3$   | 169.9          | (N/10) |
| Sodium carbonate, $\text{Na}_2\text{CO}_3$  | 53.00          | (2N)   |
| Sodium phosphate, $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$                | 119.4          | (N/2)  |
| Sodium thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$      | 124.10         | (N/2)  |
| Stannous chloride, $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$                          | 112.8          | (N)    |
| Sulphuric acid  | 49.04          | (2N)   |
| Zinc sulphate, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$                              | 143.8          | (N/2)  |

## Neutralisation Methods.

### *Standards.*

Numerous substances have been recommended for use as standards in acidimetry and alkalimetry on account of the purity of samples readily obtained.

Sodium carbonate, prepared by heating the bicarbonate (well washed with ice-cold water) at  $180-200^{\circ}\text{C}$ . until constant in weight, must be heated in the air-oven each time before use.

Organic acids (e.g. recrystallised oxalic acid) have been recommended. As phenolphthalein is used as indicator, the alkali solution employed must be free from carbonate. Such a solution is prepared by careful addition of baryta water to the caustic alkali solution.

*Phenolphthalein* cannot be used with weak alkalies such as ammonia; in titrating with alkalies, the titration should be continued until the maximum red colour is obtained; titrations with acid should proceed until the solution is quite colourless.

*Methyl orange* may be used for the titration of the alkali salts of weak acids.

*Methyl red* is recommended particularly in case solutions of less than N/10 strength are being employed.

*Combined ammonia.* The neutral solution is boiled with a measured excess of standard alkali and titrated back with standard acid, using methyl orange as indicator.

*Estimation of nitrates as ammonia.* 1 gram. of the commercial nitrate is dissolved in 250 cc. of water, 25 cc. withdrawn into the flask (preferably of copper) of an ammonia distillation apparatus, 100 cc. of dilute caustic soda and then exactly 20 cc. of titanous chloride or sulphate solution (20 per cent.) added. The solution is distilled for twenty minutes, and the ammonia produced collected in decinormal sulphuric acid; the excess is titrated with decinormal alkali. The distillation is repeated in absence of nitrate, using the same volume of titanous chloride solution, in order to ascertain the amount of ammonia due to nitrogen compounds in this reagent. (It is now stated that it is unnecessary to carry out a "blank" on the titanous chloride.)

*Estimation of total alkali in water-glass.* 1-2 gram. of water-glass are weighed out, dissolved in 50 cc. of hot water in a porcelain dish, the solution diluted to 200 cc., and titrated with normal sulphuric acid, using methyl orange as indicator.

*Valuation of borax.* (a) *Total alkali* is estimated by titration with normal sulphuric acid, using methyl orange as indicator, when all the boric acid is liberated.

(b) After heating the neutralised solution from (a) *almost* to the boiling-point, to free from carbon dioxide, it is mixed with an equal bulk of neutral glycerin solution (prepared by mixing glycerin with an equal volume of water, adding phenolphthalein, and titrating with caustic soda). The mixture is then titrated with normal caustic soda, the phenolphthalein acting as indicator. The  $B_2O_3$  is converted into metaborate ( $NaBO_2$ ).

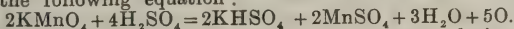
*Valuation of argol.* 2 grm. are weighed accurately into a porcelain crucible. The total amount of tartrate present is determined by igniting over a small Bunsen flame to convert into carbonate. The residue is extracted with water, the liquid filtered, and the potassium carbonate in the solution titrated with standard acid.

The percentage of bitartrate ( $KHC_4H_4O_6$ ) present is ascertained by dissolving 2-3 grm. in hot water and titrating with caustic soda, using phenolphthalein as indicator. From this the amount of potassium carbonate formed in the above ignition due to bitartrate may be calculated, and then the amount due to neutral tartrate ( $K_2C_4H_4O_6$ ), from which the percentage of neutral tartrate may be obtained.

## Oxidation Methods.

### (1) Potassium Permanganate and Potassium Dichromate.

In presence of oxidisable material, an acid solution of potassium permanganate contains available oxygen according to the following equation:



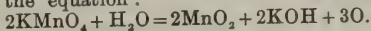
That is,  $2KMnO_4$  are equivalent to 5O. Hence a decinormal solution of potassium permanganate, 1 litre of which is to be equivalent to 8 grm. of oxygen, must contain (for use in acid solution)

$$\frac{2(158)}{2 \times 5 \times 10} = 3.16 \text{ grm. } KMnO_4 \text{ per litre.}$$

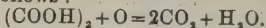
In case the permanganate is used in neutral or alkaline solution, a decinormal solution will contain

$$\frac{2(158)}{2 \times 3 \times 10} = 5.267 \text{ grm. } KMnO_4 \text{ per litre,}$$

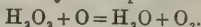
based on the equation:



In the titration of oxalic acid (in presence of sulphuric acid and at 60–70°C.), the reaction which occurs may be represented as follows:

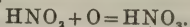


In the estimation of hydrogen peroxide (in sulphuric acid solution), the reaction may be represented as follows:



In the estimation of ferrocyanides (in presence of a large amount of sulphuric acid), the reaction involved is the oxidation of  $\text{H}_4\text{Fe}(\text{CN})_6$  to  $\text{H}_3\text{Fe}(\text{CN})_6$ .

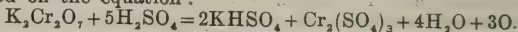
In the estimation of nitrite, it is preferable to titrate with the nitrite solution into the warm diluted permanganate, the reaction being:



Similar reasoning to the above applies to a decinormal solution of potassium dichromate (used in presence of hydrochloric acid), a decinormal solution of which contains

$$\frac{294.2}{2 \times 3 \times 10} = 4.903 \text{ grm. } \text{K}_2\text{Cr}_2\text{O}_7 \text{ per litre,}$$

based on the equation:



#### *Standards.*

Recrystallised ammonium oxalate or very carefully purified oxalic acid may be used in standardising potassium permanganate (in sulphuric acid solution at 60–70°C.).

Ferrous ammonium sulphate is available for standardising potassium permanganate (in sulphuric\* acid solution) or potassium dichromate (in hydrochloric acid solution), but must be carefully prepared, as the iron content of commercially pure samples frequently differs from the theoretical value. The indicator used in titrations with potassium dichromate is a dilute solution of potassium ferricyanide

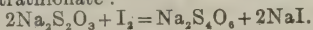
\*It has been stated that the presence of manganese sulphate prevents the interaction of hydrochloric and permanganic acids; it is, however, inadvisable to titrate with permanganate in presence of hydrochloric acid, dichromate being available in such a case. For example, in the estimation of a ferric salt, the ferric salt may be reduced (a) with zinc and sulphuric acid, the ferrous salt being titrated with permanganate; or (b) with zinc and hydrochloric acid which is much quicker, or even more rapidly with stannous chloride solution (the excess of which is oxidised by careful addition of mercuric chloride solution); in which case the ferrous salt is titrated with dichromate.



(freshly prepared from washed crystals), employed as an outside indicator on a spot plate to show when the conversion of  $\text{Fe}^{++}$  to  $\text{Fe}^{+++}$  is complete.

## (2) Iodimetry.

The following equation represents the reaction between iodine and sodium thiosulphate, resulting in the formation of sodium tetrathionate:



Sodium thiosulphate solution should be preserved in full, stoppered bottles, out of contact with air containing carbon dioxide, which causes precipitation of sulphur.

### *Standards.*

Sodium thiosulphate solution may be standardised against decinormal permanganate as follows: 25 cc. of standard permanganate are acidified with 10 cc. of dilute sulphuric acid, 10 cc. of a 10 per cent. solution of potassium iodide added, and the iodine liberated titrated with thiosulphate solution until of a pale yellow tint, and then either (i) a few cc. of a freshly prepared starch solution added and the liquid titrated until the violet colour finally disappears, or (ii) 1 cc. of a 0.5 per cent. solution of methylene blue added and the liquid titrated until the brown colour has changed through green to blue.

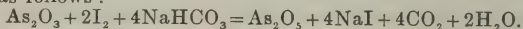
In case the thiosulphate is to be used for the determination of copper, it is preferable to standardise in the following manner: 0.3 gm. of electrolytic copper are dissolved in 10 cc. of nitric acid (1:1) in a conical flask, inclined in order to prevent spurting, the solution diluted with 20 cc. of water and boiled for a few moments to expel nitric fumes. The solution is rinsed into a beaker, sodium carbonate added until the liquid is opalescent, and then a slight excess of acetic acid added. 10 cc. of a 10 per cent. solution of potassium iodide are added and the iodine liberated titrated with thiosulphate solution until the precipitate is almost white; starch solution is then added and the liquid titrated until it remains colourless on standing for one minute.

Standard iodine solution is prepared by dissolving 13 gm. of iodine in a litre of water containing 30 gm. of potassium iodide, and is standardised against decinormal thiosulphate.

*Valuation of bleaching powder.* 10-12 gm. of sample of bleaching powder are ground to a paste with water in a porcelain mortar, and more water added. After allowing to settle, the turbid liquid is decanted into a litre flask. The

residue is ground with further amounts of water until the whole of the solid has been transferred to the flask. The liquid is made up to a litre, 25 cc. of the turbid liquid withdrawn by pipette, 10 cc. of a 10 per cent. solution of potassium iodide added, the solution acidified with acetic acid, and titrated with decinormal thiosulphate.

An alternative method is to use a standard solution of arsenious oxide, prepared by dissolving 4.95 gm. of arsenious oxide in caustic soda, acidifying with hydrochloric acid, and adding an excess of sodium bicarbonate. The reaction used is as follows :



A measured excess of arsenious oxide is added to the bleaching powder solution prepared as above, and the excess titrated with decinormal iodine; or, the bleaching powder solution may be titrated directly with the standard arsenious oxide solution, using starch-iodide paper as an external indicator.

*Estimation of chlorate.* Owing to the possible presence of free chlorine in hydrochloric acid and of iodate in the potassium iodide, a "blank" must be carried out in this estimation. 10 gm. of potassium iodide (weighed to the nearest decigram) dissolved in about 50 cc. of water, and 20 cc. of concentrated hydrochloric acid, are placed in each of two 250 cc. bottles with well-fitting glass stoppers. About 0.5 gm. of commercial chlorate is dissolved in water, and added to the contents of one bottle. The stoppers are fastened to the necks of the bottles. The bottles are immersed in a steam bath for twenty minutes, removed and allowed to cool. The contents of the bottle to which chlorate has been added are made up to 250 cc. in a measuring flask, and 25 cc. titrated with decinormal thiosulphate, using starch or methylene blue as indicator. The contents of the other bottle are titrated direct, and the suitable correction subtracted from the previous titration.

*Determination of sulphite.* 5 gm. of commercial sulphite are dissolved in 250 cc. of water. 25 cc. are withdrawn, a measured excess of decinormal iodine added, and the excess titrated with decinormal thiosulphate.

### (3) Titanous Chloride and Methylene Blue.

For many purposes the use of standard solutions (N/50 to N/40) of these two reagents has decided advantages over the methods at present more frequently adopted. Examples are the estimation of iron as ferric salt, chromium as chromate, stannous chloride, and of other substances which



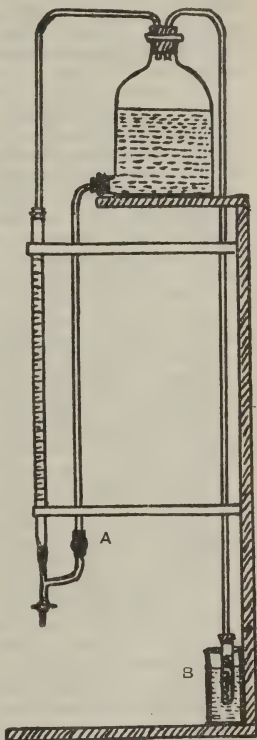
act as, or may be quantitatively converted into, oxidising or reducing agents. Contrary to general impression, these reagents are comparatively cheap.

The standard solution of methylene blue is quite stable, but the preservation of standard titanous chloride necessitates the use of a special storage apparatus. The storage vessel is filled with a thoroughly mixed solution containing 25 cc. of 20 per cent. titanous chloride solution and 50 cc. of concentrated hydrochloric acid per litre. By opening the burette tap, a current of hydrogen from the generator, B, may be passed through the apparatus for five minutes. The contents of the storage vessel are again mixed, and the burette filled by opening the bead valve at A. After running off several cc., the apparatus is ready for use.

A standard solution of methylene blue is prepared by dissolving 4-5 gm. of the hydrochloride (free from zinc) in 500 cc. of hot water, and diluting to a litre. A standard solution of pure potassium chlorate is also prepared by dissolving 0.6-0.7 gm. in a litre of cold, recently boiled water.

*Standardisation of solutions.*

(1) 50 cc. of the methylene blue solution are withdrawn into an 8 oz. conical flask, an equal volume of dilute hydrochloric acid added, and a current of carbon dioxide passed into the flask. The liquid is heated to boiling, and titrated whilst warm with the titanous chloride solution until the blue colour disappears. The current of carbon dioxide is maintained, and 25 cc. of the potassium chlorate solution added to the contents of the flask, the solution warmed to about  $40^{\circ}\text{C}$ . if necessary (to obtain a sharp end-point), and the warm



solution titrated with titanous chloride. The second titration gives the volume of titanous chloride equivalent to the oxygen available in 25 cc. of the standard potassium chlorate solution (due to its reduction to chloride by the reduced methylene blue), and hence the oxygen equivalent and iron equivalent of 1 cc. of titanous chloride may be calculated. The volume of titanous chloride equivalent to 50 cc. of methylene blue is known from the first titration, and from this the oxygen equivalent and iron equivalent of 1 cc. of methylene blue may be calculated.

(2) In case pure ferrous ammonium sulphate is available, and an iron estimation is to be carried out by means of titanous chloride, the following method may be used for standardising the titanous chloride solution: \* 3-4 gm. of ferrous ammonium sulphate are dissolved in 100 cc. of water, an equal volume of dilute sulphuric acid added, and the solution made up to 250 cc. in a measuring flask. 25 cc. are oxidised with dilute potassium permanganate, an excess of which may be destroyed by adding hydrochloric acid and boiling for several minutes. A current of carbon dioxide is passed into the flask, 20 cc. of potassium thiocyanate solution added, and the solution titrated with titanous chloride solution until colourless.

Another method is to add 2 drops of methylene blue solution to the ferric salt solution, warm to about 40°C. and titrate with titanous chloride solution until decolorised. As the methylene blue requires 2 drops of titanous chloride for its decoloration, 0.1 cc. must be subtracted from the titration.

In case method (2) is used, as the titanous chloride solution oxidises slowly even in the special storage apparatus, it is convenient to keep a standard solution of iron alum, containing about 14 gm. per litre and acidified with sulphuric acid, for re-standardising purposes; this solution remains the same strength for an indefinite period, and may be standardised by titration with titanous chloride immediately after this reagent has been standardised as above. This is not necessary if the titanous chloride is to be used in conjunction with standard methylene blue, as the titration of the latter solution, which keeps its standard indefinitely, will serve as standardisation.

In practice it has been found advisable to standardise the titanous chloride solution against a pure sample of the

---

\* See Knecht and Hibbert, *New Reduction Methods in Volumetric Analysis*.

substance to be estimated, whenever possible, e.g. in estimating chromates, it should be standardised against pure potassium dichromate.

*Determination of Ferric salt.* 25 cc. of the ferric salt solution is diluted to 100 cc. with water, boiled for a few moments, allowed to cool to about  $40^{\circ}\text{C}$ . in an atmosphere of carbon dioxide, two drops of methylene blue added, and titrated as in method of standardisation (2) above. The titanous chloride is standardised against standard iron alum solution.

Another convenient method is as follows: 25 cc. of standard methylene blue are reduced with titanous chloride as in method of standardisation (1), by which means the reagent is standardised; 25 cc. of the ferric salt solution are added, and the methylene blue produced by the reduction of the ferric salt titrated with titanous chloride.

*Estimation of Chlorate.* The procedure will be clear from a consideration of method of standardisation (1) above. The process is unaffected by the presence of perchlorates, which do not oxidise reduced methylene blue under these conditions.

*Estimation of Chromium or Chromate.\** 50 cc. of the solution containing a suitable amount of chromium are taken, a slight excess of caustic soda added, and then small amounts of sodium peroxide are added until the oxidation and solution of the chromium hydroxide is complete. After boiling for ten minutes to destroy the excess of sodium peroxide, the solution is diluted to 250 cc. 25 cc. of this solution are added to reduced methylene blue solution (the chromate is reduced to a chromic salt), and the methylene blue produced is titrated. A satisfactory method of estimating dichromates is as follows:—25 cc. of approx. N/30 dichromate and 10 cc. of N/30 iron alum are warmed to  $60^{\circ}\text{C}$ . and standardised titanous chloride added until the solution is a clear blue-green; thiocyanate is added, and the titration continued until a clear green solution is obtained.

*Estimation of Stannous Chloride.* 1 grm. of commercial sample is dissolved in 50 cc. dilute hydrochloric acid, and made up to 250 cc. with cold, recently boiled water. 25 cc. are withdrawn into a conical flask through which a current of carbon dioxide is maintained, an equal volume of concen-

---

\* Chromium, vanadium, and iron may be estimated in presence of one another (Atack, *Analyst*, 1913).

trated hydrochloric acid added, and the solution titrated with standard methylene blue\* until the blue colour persists. (In case the concentrated hydrochloric acid contains free chlorine, as is frequently the case, the necessary correction for its action in oxidising some stannous chloride is readily made by repeating the titration, using double the volume (50 cc.) of hydrochloric acid, when any decrease in the volume of methylene blue used is to be added to the first titration.)

*Valuation of Hydrosulphite.* 50 cc. of standard methylene blue are measured into a conical flask through which a current of carbon dioxide is maintained, 0.1 to 0.2 grm. of sodium hydrosulphite introduced from a weighing bottle, 10 cc. of acetic acid added, the liquid warmed, and the excess of methylene blue determined by means of titanous chloride (previously standardised against 25 cc. of the standard methylene blue). The percentage of  $\text{Na}_2\text{S}_2\text{O}_4$  in the sample is calculated on the basis that one molecule requires one atom of oxygen for its oxidation.

## Precipitation Methods.

### (1) Silver Nitrate and Ammonium Thiocyanate.

Standard silver nitrate solution may be standardised against pure, fused sodium chloride.

In estimating halides or cyanide (in *neutral* solution) by means of decinormal silver nitrate, several drops of (neutral) potassium chromate solution are added, and the titration continued until the precipitate becomes reddish. Cyanides may be titrated direct with silver nitrate, the soluble double cyanide being formed until half the cyanide present has been converted into silver cyanide; further addition of silver nitrate gives an opalescence which marks the end-point, due to the precipitation of silver cyanide.

Standard thiocyanate solution may be standardised against decinormal silver nitrate or against pure silver foil dissolved in nitric acid (1:1). Ammonium thiocyanate solution is added to the *acid* solution of the silver salt containing ferric sulphate until, after allowing to settle, the clear liquid above the white ppt. has acquired a permanent blood-red

---

\* A method of standardising methylene blue which does not necessitate the use of titanous chloride has been described (Atack, *J. Soc. Dyers and Col.*, 1913, p. 9).

colour. A suitable solution of ferric sulphate is prepared by oxidising 100 cc. of a saturated solution of ferrous sulphate with 50 cc. of concentrated nitric acid, boiling to expel nitric fumes (nitrous acid must be absent). The presence of free nitric acid is essential, as lead, copper and zinc do not then affect the titration; mercury must be absent, and large amounts of copper mask the end-point.

### (2) Potassium Ferrocyanide.

It is convenient to prepare a solution of which 1 cc. corresponds approximately to 0.01 gm. of zinc by dissolving 45 gm. of the pure salt in a litre of water. This solution is standardised as follows: 2.5 gm. of pure zinc are dissolved in 25 cc. of hydrochloric acid (1 : 1) and the solution diluted to 250 cc. 25 cc. of this standard zinc solution is withdrawn, diluted to 200 cc., 5 gm. of ammonium chloride and 10 cc. of concentrated hydrochloric acid added, and the solution heated to 80°C. Ferrocyanide solution is added until a drop of the liquid gives a brown coloration with a saturated solution of uranium acetate on a spot plate. The precipitation of the zinc ferrocyanide does not take place immediately; hence the solution must be allowed to stand for one minute, the spot test repeated, and further ferrocyanide solution added if necessary.

### (3) Sodium Sulphide.

5-6 gm. of sodium sulphide ("rock" or "concentrated," *i.e.*, 60%  $\text{Na}_2\text{S}$ ) or 10-12 gm. of sodium sulphide "crystals" are dissolved in approximately 200 cc. water, allowed to stand overnight, and then filtered, and the solution made up to 250 cc.

A standard zinc solution is prepared by dissolving 57.5 gm. of zinc sulphate (crystals,  $7\text{H}_2\text{O}$ ) in water or by dissolving 13.07 gm. pure metallic zinc in dilute hydrochloric acid, treating the solution with ammonia until the precipitate which forms just dissolves, and diluting to a litre.

The sulphide solution is standardised by titrating 50 cc. with the zinc solution, using a dilute solution of nickel sulphate on a spot-plate as an external indicator. A black or grey precipitate will be shown until all the sulphide is precipitated as zinc sulphide.

The sulphide solution is used for the determination of zinc, copper, nickel, and cobalt, whilst the zinc solution may be used for the determination of sodium sulphide.

# FACTORS FOR QUANTITATIVE ANALYSIS.

Calculated from International Atomic Weights, 1917.

| Weighed as.                    | Required.               | Factor. | Log.    |
|--------------------------------|-------------------------|---------|---------|
| <i>Aluminium.</i>              |                         |         |         |
| $\text{Al}_2\text{O}_3$        | Al                      | 0.53034 | 1.72455 |
|                                | $\text{AlCl}_3$         | 2.61220 | 0.41700 |
| $\text{AlPO}_4$                | $\text{Al}_2\text{O}_3$ | 0.41837 | 1.62156 |
| <i>Ammonium</i>                |                         |         |         |
| $\text{NH}_4\text{Cl}$         | $\text{NH}_3$           | 0.31836 | 1.50292 |
|                                | $\text{NH}_4$           | 0.33702 | 1.52766 |
|                                | $\text{NH}_4\text{OH}$  | 0.65489 | 1.81617 |
| $(\text{NH}_4)_2\text{PtCl}_6$ | $\text{NH}_3$           | 0.07673 | 2.88494 |
|                                | $\text{NH}_4$           | 0.08123 | 2.90968 |
|                                | N                       | 0.06311 | 2.80007 |
|                                | $\text{NH}_4\text{Cl}$  | 0.24095 | 1.38193 |
| Pt                             | $\text{NH}_3$           | 0.17452 | 1.24186 |
|                                | $\text{NH}_4$           | 0.18475 | 1.26660 |
|                                | N                       | 0.14355 | 1.15699 |
|                                | $\text{NH}_4\text{Cl}$  | 0.54809 | 1.73885 |
| $(\text{NH}_4)_2\text{SO}_4$   | $\text{NH}_3$           | 0.25781 | 1.41130 |
| <i>Antimony.</i>               |                         |         |         |
| $\text{Sb}_2\text{O}_3$        | Sb                      | 0.83354 | 1.92093 |
|                                | $\text{Sb}_2\text{S}_3$ | 1.16705 | 0.06709 |
|                                | $\text{SbO}_3$          | 1.16643 | 0.06686 |
| $\text{Sb}_2\text{O}_4$        | Sb                      | 0.78975 | 1.89749 |
|                                | $\text{Sb}_2\text{O}_3$ | 0.94746 | 1.97656 |
|                                | $\text{Sb}_2\text{O}_5$ | 1.05255 | 0.02225 |
| $\text{Sb}_2\text{O}_6$        | Sb                      | 0.75031 | 1.87524 |
|                                | $\text{Sb}_2\text{S}_3$ | 1.05050 | 0.02140 |
|                                | $\text{Sb}_2\text{O}_3$ | 0.90015 | 1.95431 |
| $\text{Sb}_2\text{S}_3$        | Sb                      | 0.71424 | 1.85384 |
|                                | $\text{Sb}_2\text{O}_3$ | 0.85686 | 1.93291 |
|                                | $\text{Sb}_2\text{O}_5$ | 0.95192 | 1.97860 |
| $\text{NaHSb}_2\text{O}_7$     | $\text{SbO}_3$          | 0.84365 | 1.92617 |
|                                | $\text{Sb}_2\text{O}_3$ | 0.72026 | 1.85749 |
|                                | $\text{Sb}_2\text{O}_5$ | 0.80017 | 1.90318 |



## Factors for Quantitative Analysis—(continued).

| Weighed as.                        | Required.               | Factor  | Log.    |
|------------------------------------|-------------------------|---------|---------|
| <i>Arsenic.</i>                    |                         |         |         |
| $\text{As}_2\text{S}_3$            | As                      | 0.60918 | 1.78475 |
|                                    | $\text{As}_2\text{O}_3$ | 0.80423 | 1.90538 |
|                                    | $\text{As}_2\text{O}_5$ | 0.93426 | 1.97047 |
|                                    | $\text{AsO}_4$          | 1.12930 | 0.05281 |
| $\text{As}_2\text{O}_3$            | As                      | 0.75746 | 1.87937 |
|                                    | $\text{AsO}_3$          | 1.24243 | 0.09431 |
|                                    | $\text{As}_2\text{O}_5$ | 1.16170 | 0.06509 |
|                                    | $\text{AsO}_4$          | 1.40420 | 0.14743 |
| $\text{As}_2\text{O}_5$            | As                      | 0.65204 | 1.81428 |
|                                    | $\text{As}_2\text{O}_3$ | 0.86082 | 1.93491 |
|                                    | $\text{AsO}_3$          | 1.06960 | 0.02922 |
|                                    | $\text{AsO}_4$          | 1.20875 | 0.08234 |
| $\text{Mg}_2\text{As}_2\text{O}_7$ | $\text{As}_2\text{O}_3$ | 0.63731 | 1.80435 |
|                                    | $\text{As}_2\text{O}_5$ | 0.74035 | 1.86944 |
|                                    | $\text{AsO}_4$          | 0.89492 | 1.95178 |
|                                    | $\text{As}_2\text{S}_3$ | 0.79246 | 1.89897 |
|                                    | $\text{As}_2\text{S}_5$ | 0.99869 | 1.99943 |
|                                    | $\text{AsO}_4$          | 0.79187 | 1.89866 |
| <i>Barium.</i>                     |                         |         |         |
| $\text{BaSO}_4$                    | Ba                      | 0.58848 | 1.76973 |
|                                    | BaO                     | 0.65701 | 1.81758 |
|                                    | $\text{BaCl}_2$         | 0.89230 | 1.95051 |
| $\text{BaCO}_3$                    | Ba                      | 0.69598 | 1.84260 |
|                                    | BaO                     | 0.77706 | 1.89045 |
|                                    | $\text{BaCl}_2$         | 1.05533 | 0.02338 |
| BaO                                | Ba                      | 0.89568 | 1.95215 |
| $\text{BaCrO}_4$                   | Ba                      | 0.54216 | 1.73413 |
|                                    | BaO                     | 0.60531 | 1.78198 |
|                                    | $\text{BaCl}_2$         | 0.82207 | 1.91491 |
| $\text{BaSiF}_6$                   | Ba                      | 0.49118 | 1.69124 |
|                                    | BaO                     | 0.54839 | 1.73909 |
| $\text{BaCl}_2$                    | Ba                      | 0.65951 | 1.81922 |
|                                    | BaO                     | 0.73633 | 1.86707 |
| <i>Bismuth.</i>                    |                         |         |         |
| $\text{Bi}_2\text{O}_3$            | Bi                      | 0.89654 | 1.95257 |
| $\text{Bi}_2\text{S}_3$            | Bi                      | 0.81221 | 1.90967 |
|                                    | $\text{Bi}_2\text{O}_3$ | 0.90594 | 1.95710 |
| <i>Boron.</i>                      |                         |         |         |
| $\text{B}_2\text{O}_3$             | B                       | 0.31429 | 1.49733 |
| <i>Bromine.</i>                    |                         |         |         |
| AgBr                               | Br                      | 0.42556 | 1.62896 |
|                                    | HBr                     | 0.43092 | 1.63440 |

## Factors for Quantitative Analysis—(continued).

| Weighed as.       | Required.          | Factor. | Log.    |
|-------------------|--------------------|---------|---------|
| <i>Cadmium.</i>   |                    |         |         |
| CdO               | Cd                 | 0.87540 | 1.94221 |
|                   | CdS                | 1.12510 | 0.05119 |
| CdS               | Cd                 | 0.77807 | 1.89102 |
|                   | CdO                | 0.88882 | 1.94881 |
| <i>Calcium.</i>   |                    |         |         |
| CaO               | Ca                 | 0.71465 | 1.85409 |
|                   | CaCl <sub>2</sub>  | 1.97945 | 0.29655 |
| CaSO <sub>4</sub> | Ca                 | 0.29435 | 1.46886 |
|                   | CaO                | 0.41188 | 1.61477 |
| CaCO <sub>3</sub> | CaCl <sub>2</sub>  | 0.81530 | 1.91132 |
|                   | Ca                 | 0.40041 | 1.60250 |
|                   | CaO                | 0.56029 | 1.74841 |
|                   | CaCl <sub>2</sub>  | 1.10907 | 0.04496 |
| CO <sub>2</sub>   | CaCO <sub>3</sub>  | 2.27415 | 0.35682 |
| <i>Carbon.</i>    |                    |         |         |
| CO <sub>2</sub>   | C                  | 0.27280 | 1.43586 |
|                   | CO <sub>3</sub>    | 1.36360 | 0.13469 |
| CaCO <sub>3</sub> | CO <sub>2</sub>    | 0.43972 | 1.64318 |
|                   | CO <sub>3</sub>    | 0.59962 | 1.77787 |
| BaCO <sub>3</sub> | CO <sub>2</sub>    | 0.22295 | 1.34821 |
|                   | CO <sub>3</sub>    | 0.30402 | 1.48290 |
| <i>Chlorine.</i>  |                    |         |         |
| AgCl              | Cl                 | 0.24738 | 1.39337 |
|                   | HCl                | 0.25442 | 1.40555 |
|                   | ClO <sub>3</sub>   | 0.58225 | 1.76511 |
|                   | ClO <sub>4</sub>   | 0.69388 | 1.84128 |
|                   | NaCl               | 0.40784 | 1.61049 |
|                   | KCl                | 0.52016 | 1.71614 |
|                   | NaClO <sub>3</sub> | 0.74270 | 1.87081 |
|                   | KClO <sub>3</sub>  | 0.85502 | 1.93198 |



## Factors for Quantitative Analysis—(continued).

| Weighed as.                          | Required                 | Factor. | Log.    |
|--------------------------------------|--------------------------|---------|---------|
| <i>Chromium.</i>                     |                          |         |         |
| $\text{Cr}_2\text{O}_3$              | Cr                       | 0.68422 | 1.83519 |
|                                      | $\text{CrO}_3$           | 1.31580 | 0.11919 |
|                                      | $\text{CrO}_4$           | 1.52635 | 0.18365 |
|                                      | $\text{Cr}_2\text{O}_7$  | 1.42106 | 0.15261 |
| $\text{BaCrO}_4$                     | Cr                       | 0.20523 | 1.31224 |
|                                      | $\text{CrO}_3$           | 0.39467 | 1.59624 |
|                                      | $\text{CrO}_4$           | 0.45782 | 1.66070 |
|                                      | $\text{Cr}_2\text{O}_3$  | 0.29995 | 1.47706 |
| $\text{PbCrO}_4$                     | $\text{Cr}_2\text{O}_7$  | 0.42626 | 1.62967 |
|                                      | Cr                       | 0.16079 | 1.20653 |
|                                      | $\text{CrO}_3$           | 0.30941 | 1.49053 |
|                                      | $\text{CrO}_4$           | 0.35892 | 1.55499 |
| $\text{K}_2\text{Cr}_2\text{O}_7$    | $\text{Cr}_2\text{O}_3$  | 0.23515 | 1.37134 |
|                                      | $\text{Cr}_2\text{O}_7$  | 0.33416 | 1.52395 |
|                                      | Cr                       | 0.35350 | 1.54839 |
|                                      | $\text{Cr}_2\text{O}_3$  | 0.51666 | 1.71320 |
| <i>Cobalt.</i>                       | $\text{CrO}_3$           | 0.67981 | 1.83239 |
|                                      | $\text{CrO}_4$           | 0.78859 | 1.89685 |
|                                      | $\text{Cr}_2\text{O}_7$  | 0.73420 | 1.86581 |
|                                      | CoO                      | 1.27131 | 0.10426 |
| Co                                   | Co                       | 0.78658 | 1.89574 |
| CoO                                  | Co                       | 0.38038 | 1.58022 |
| $\text{CoSO}_4$                      | CoO                      | 0.48359 | 1.68448 |
| $\text{K}_3\text{Co}(\text{NO}_2)_6$ | Co                       | 0.13037 | 1.11517 |
|                                      | CoO                      | 0.16574 | 1.21943 |
| <i>Copper.</i>                       |                          |         |         |
| CuO                                  | Cu                       | 0.79892 | 1.90250 |
| $\text{Cu}_2\text{S}$                | Cu                       | 0.79864 | 1.90235 |
|                                      | CuO                      | 0.99963 | 1.99984 |
|                                      | $\text{Cu}_2\text{O}$    | 0.89913 | 1.95382 |
| <i>Cyanogen.</i>                     |                          |         |         |
| Ag                                   | CN                       | 0.24115 | 1.38228 |
| AgCN                                 | CN                       | 0.19429 | 1.28845 |
|                                      | HCN                      | 0.20173 | 1.30497 |
| <i>Fluorine.</i>                     |                          |         |         |
| $\text{CaF}_2$                       | F                        | 0.48675 | 1.68730 |
|                                      | HF                       | 0.51258 | 1.70976 |
| $\text{BaSiF}_6$                     | F                        | 0.40762 | 1.61025 |
|                                      | HF                       | 0.42924 | 1.63270 |
|                                      | $\text{H}_2\text{SiF}_6$ | 0.51602 | 1.71267 |
|                                      | KF                       | 0.41513 | 1.61818 |

## Factors for Quantitative Analysis—(continued).

| Weighed as.                                   | Required.                      | Factor. | Log.    |
|---|--------------------------------|---------|---------|
| <i>Gold.</i>                                  |                                |         |         |
| Au  | AuCl <sub>3</sub>              | 1.53943 | 0.18736 |
|   | Au <sub>2</sub> O <sub>3</sub> | 1.12170 | 0.04988 |
| <i>Hydrogen.</i>                              |                                |         |         |
| H <sub>2</sub> O                              | H                              | 0.11192 | 1.04884 |
| <i>Iodine.</i>                                |                                |         |         |
| I <sub>2</sub> O <sub>5</sub>                 | I                              | 0.76037 | 1.88102 |
|   | HI                             | 0.76638 | 1.88445 |
| AgI   | I                              | 0.54054 | 1.73283 |
|   | HI                             | 0.54482 | 1.73626 |
| PdI <sub>2</sub>                              | I                              | 0.70402 | 1.84760 |
|   | HI                             | 0.70964 | 1.85103 |
| <i>Iron.</i>                                  |                                |         |         |
| Fe <sub>2</sub> O <sub>3</sub>                | Fe                             | 0.69939 | 1.84472 |
| <i>Lead.</i>                                  |                                |         |         |
| PbO   | Pb                             | 0.92833 | 1.96770 |
| PbO <sub>2</sub>                              | Pb                             | 0.86622 | 1.93763 |
| PbS   | Pb                             | 0.86580 | 1.93742 |
|   | PbO                            | 0.93265 | 1.96972 |
|   | PbSO <sub>4</sub>              | 1.26720 | 0.10285 |
| PbCl <sub>2</sub>                             | Pb                             | 0.74500 | 1.87216 |
| PbSO <sub>4</sub>                             | Pb                             | 0.68323 | 1.83457 |
|   | PbO                            | 0.73599 | 1.86687 |
|   | PbS                            | 0.78914 | 1.89715 |
| <i>Lithium</i>                                |                                |         |         |
| Li <sub>2</sub> CO <sub>3</sub>               | Li                             | 0.18786 | 1.27383 |
| Li <sub>3</sub> PO <sub>4</sub>               | Li                             | 0.17970 | 1.25454 |
|   | LiCl                           | 1.09785 | 0.04055 |
|   | Li <sub>2</sub> O              | 0.38684 | 1.58753 |
| <i>Magnesium.</i>                             |                                |         |         |
| MgO   | Mg                             | 0.60317 | 1.78044 |
| Mg <sub>2</sub> P <sub>2</sub> O <sub>7</sub> | Mg                             | 0.21839 | 1.33923 |
|   | MgO                            | 0.36207 | 1.55879 |
|   | MgSO <sub>4</sub>              | 1.08100 | 0.03383 |
| MgSO <sub>4</sub>                             | Mg                             | 0.20203 | 1.30540 |
|   | MgO                            | 0.33493 | 1.52496 |
| <i>Manganese.</i>                             |                                |         |         |
| MnO   | Mn                             | 0.77442 | 1.88898 |
| Mn <sub>3</sub> O <sub>4</sub>                | Mn                             | 0.72027 | 1.85749 |
|   | MnO                            | 0.93026 | 1.96851 |
|   | MnO <sub>4</sub>               | 1.55933 | 0.19297 |
| MnS   | Mn                             | 0.63145 | 1.80033 |
|   | MnO                            | 0.81538 | 1.91136 |
|   | MnO <sub>4</sub>               | 1.36717 | 0.13582 |
| MnSO <sub>4</sub>                             | Mn                             | 0.36380 | 1.56086 |
|   | MnO                            | 0.46977 | 1.67188 |

## Factors for Quantitative Analysis—(continued).

| Weighed as.  | Required.                                       | Factor. | Log.    |
|--|---|---------|---------|
| <i>Mercury.</i>  |   |         |         |
| Hg   | HgO   | 1.07977 | 0.03333 |
|  | HgS   | 1.15983 | 0.06439 |
|  | Hg <sub>2</sub> O                               | 1.03980 | 0.01696 |
|  | Hg <sub>2</sub> Cl <sub>2</sub>                 | 1.17667 | 0.07069 |
| HgO  | Hg  | 0.92613 | 1.96667 |
|  | HgS   | 1.07415 | 0.03106 |
| HgS  | Hg  | 0.86220 | 1.93561 |
| Hg <sub>2</sub> Cl <sub>2</sub>  | Hg  | 0.84977 | 1.92931 |
|  | HgO   | 0.91757 | 1.96264 |
| <i>Molybdenum.</i>   |   |         |         |
| MoS <sub>3</sub>   | Mo  | 0.49952 | 1.69856 |
|  | MoO <sub>2</sub>                                | 0.66605 | 1.82350 |
| MoO <sub>2</sub>   | Mo  | 0.75000 | 1.87506 |
| <i>Nickel.</i>   |   |         |         |
| NiO  | Ni  | 0.78575 | 1.89529 |
| NiSO <sub>4</sub>  | Ni  | 0.37922 | 1.57889 |
|  | NiO   | 0.48261 | 1.68360 |
| (C <sub>4</sub> H <sub>7</sub> O <sub>2</sub> N <sub>2</sub> ) <sub>2</sub> Ni   |   |         |         |
| (Dimethylglyoxime ppt.)  | Ni  | 0.20311 | 1.30777 |
| (C <sub>14</sub> H <sub>11</sub> O <sub>2</sub> N <sub>2</sub> ) <sub>2</sub> Ni |   |         |         |
| (α-Benzildioxime ppt.)   | Ni  | 0.10927 | 1.03848 |
| <i>Nitrogen.</i>   |   |         |         |
| (See also Ammonium.)   |   |         |         |
| (NH <sub>4</sub> ) <sub>2</sub> PtCl <sub>6</sub>                                | N   | 0.06310 | 1.80005 |
|  | NO <sub>3</sub>                                 | 0.27930 | 1.44607 |
| Pt   | N   | 0.14355 | 1.15699 |
|  | NO <sub>3</sub>                                 | 0.63535 | 1.80301 |
| <i>Palladium.</i>  |   |         |         |
| PdI <sub>2</sub>   | Pd  | 0.29594 | 1.47120 |
| <i>Phosphorus.</i>   |   |         |         |
| P <sub>2</sub> O <sub>5</sub>  | P   | 0.43694 | 1.64042 |
|  | PO <sub>4</sub>                                 | 1.33783 | 0.12640 |
| Mg <sub>2</sub> P <sub>2</sub> O <sub>7</sub>                                    | P   | 0.27873 | 1.44519 |
|  | PO <sub>4</sub>                                 | 0.85343 | 1.93117 |
|  | P <sub>2</sub> O <sub>5</sub>                   | 0.63793 | 1.80477 |
|  | P <sub>2</sub> O <sub>7</sub>                   | 0.78161 | 1.89299 |
|  | PO <sub>3</sub>                                 | 0.70978 | 1.85112 |
| Phosphomolybdate ppt.  | P   | 0.01640 | 2.21484 |
|  | P <sub>2</sub> O <sub>5</sub>                   | 0.03753 | 2.57438 |
|  | Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> | 0.08196 | 2.91360 |

## Factors for Quantitative Analysis—(continued).

| Weighed as.   | Required.                | Factor. | Log.    |
|---|--------------------------|---------|---------|
| <i>Platinum.</i>  |                          |         |         |
| $(\text{NH}_4)_2\text{PtCl}_6$                                  | Pt                       | 0.43960 | 1.64306 |
|   | $\text{PtCl}_4$          | 0.75904 | 1.88026 |
|   | $\text{PtCl}_6$          | 0.91875 | 1.96319 |
| Pt  | $\text{PtCl}_4$          | 1.72663 | 0.23720 |
|   | $\text{PtCl}_6$          | 2.08990 | 0.32013 |
|   | Pt                       | 0.40151 | 1.60370 |
| $\text{K}_2\text{PtCl}_6$                                       | $\text{PtCl}_4$          | 0.69327 | 1.84090 |
|   | $\text{PtCl}_6$          | 0.83914 | 1.92383 |
|   | Pt                       |         |         |
| <i>Potassium</i>  |                          |         |         |
| KCl   | K                        | 0.52441 | 1.71967 |
| $\text{K}_2\text{SO}_4$   | K                        | 0.44875 | 1.65201 |
|   | $\text{K}_2\text{O}$     | 0.54056 | 1.73285 |
|   | KCl                      | 0.85574 | 1.93234 |
| $\text{KNO}_3$  | K                        | 0.38672 | 1.58139 |
| $\text{K}_2\text{PtCl}_6$                                       | K                        | 0.16085 | 1.20643 |
|   | $\text{K}_2\text{O}$     | 0.19376 | 1.28727 |
|   | KCl                      | 0.30674 | 1.48676 |
| $\text{KClO}_4$   | $\text{K}_2\text{CO}_3$  | 0.28428 | 1.45375 |
|   | K                        | 0.28219 | 1.45054 |
|   | KCl                      | 0.53811 | 1.73087 |
| $\text{K}_2\text{NaCo}(\text{NO}_2)_6 \cdot \text{H}_2\text{O}$ | K                        | 0.17215 | 1.23591 |
| <i>Silicon.</i>   |                          |         |         |
| $\text{SiF}_4$  | $\text{SiO}_2$           | 0.57815 | 1.76204 |
| $\text{SiO}_2$  | Si                       | 0.46932 | 1.67147 |
|   | $\text{SiO}_3$           | 1.26533 | 0.10220 |
|   | $\text{SiO}_4$           | 1.53066 | 0.18488 |
| $\text{BaSiF}_6$  | $\text{H}_2\text{SiF}_6$ | 0.51602 | 1.71267 |
|   | $\text{SiO}_2$           | 0.21561 | 1.33367 |
|   | $\text{SiF}_4$           | 0.37294 | 1.57163 |
| <i>Silver.</i>  |                          |         |         |
| AgCl  | Ag                       | 0.75262 | 1.87657 |
| AgBr  | Ag                       | 0.57444 | 1.75924 |
| AgI   | Ag                       | 0.45945 | 1.66224 |
| AgCN  | Ag                       | 0.80572 | 1.90618 |
| Ag  | AgCl                     | 1.32870 | 0.12343 |
|   | AgBr                     | 1.74085 | 0.24076 |

## Factors for Quantitative Analysis—(continued).

| Weighed as.                                  | Required.                | Factor. | Log.    |
|--|--------------------------|---------|---------|
| <i>Sodium.</i>                               |                          |         |         |
| $\text{Na}_2\text{O}$                        | Na                       | 0.74194 | 1.87037 |
| NaCl   | Na                       | 0.39344 | 1.59487 |
| $\text{Na}_2\text{SO}_4$                     | $\text{Na}_2\text{O}$    | 0.53029 | 1.72451 |
|  | Na                       | 0.32381 | 1.51029 |
|  | $\text{Na}_2\text{O}$    | 0.43644 | 1.63992 |
|  | NaCl                     | 0.82302 | 1.91541 |
| $\text{Na}_2\text{H}_2\text{Sb}_2\text{O}_7$ | Na                       | 0.11488 | 1.06025 |
|  | $\text{Na}_2\text{O}$    | 0.15484 | 1.18988 |
|  | NaCl                     | 0.29200 | 1.46537 |
|  | Na                       | 0.43395 | 1.63743 |
| $\text{Na}_2\text{CO}_3$                     | $\text{Na}_2\text{O}$    | 0.58487 | 1.76706 |
| <i>Strontium.</i>                            |                          |         |         |
| $\text{SrSO}_4$                              | Sr                       | 0.47706 | 1.67857 |
|  | SrO                      | 0.56417 | 1.75141 |
| SrO  | Sr                       | 0.84560 | 1.92716 |
| $\text{SrCO}_3$                              | Sr                       | 0.59356 | 1.77346 |
|  | SrO                      | 0.70194 | 1.84630 |
| <i>Sulphur.</i>                              |                          |         |         |
| $\text{BaSO}_4$                              | S                        | 0.13734 | 1.13780 |
|  | $\text{SO}_2$            | 0.27443 | 1.43843 |
|  | $\text{SO}_3$            | 0.34297 | 1.53526 |
|  | $\text{SO}_4$            | 0.41151 | 1.61438 |
|  | $\text{S}_2\text{O}_3$   | 0.24016 | 1.38049 |
|  | $\text{H}_2\text{SO}_4$  | 0.42023 | 1.62349 |
|  | $\text{Na}_2\text{SO}_4$ | 0.60858 | 1.78432 |
|  | $\text{H}_2\text{S}$     | 0.14598 | 1.16429 |
| $\text{CdS}$                                 | S                        | 0.22193 | 1.34621 |
|  | $\text{H}_2\text{S}$     | 0.23589 | 1.37270 |
| <i>Tin.</i>                                  |                          |         |         |
| $\text{SnO}_2$                               | Sn                       | 0.78766 | 1.89634 |
|  | $\text{SnCl}_2$          | 1.25830 | 0.09978 |
| <i>Titanium.</i>                             |                          |         |         |
| $\text{TiO}_2$                               | Ti                       | 0.60051 | 1.77852 |
| <i>Tungsten.</i>                             |                          |         |         |
| $\text{WO}_3$                                | W                        | 0.79310 | 1.89933 |
| <i>Uranium.</i>                              |                          |         |         |
| $\text{U}_2\text{O}_5$                       | U                        | 0.84808 | 1.92844 |
| $\text{K}_2\text{U}_2\text{O}_7$             | U                        | 0.71467 | 1.85410 |
| <i>Vanadium.</i>                             |                          |         |         |
| $\text{V}_2\text{O}_5$                       | V                        | 0.56044 | 1.74853 |
| <i>Zinc.</i>                                 |                          |         |         |
| ZnO  | Zn                       | 0.80339 | 1.90492 |
|  | ZnS                      | 1.19737 | 0.07823 |
| ZnS  | Zn                       | 0.67088 | 1.82664 |
|  | ZnO                      | 0.83516 | 1.92177 |

## GAS ANALYSIS.

In the qualitative examination of a gas the first observations are of colour, odour, combustibility, and ability to support combustion. Then it is ascertained whether the gas or part of it can be removed by certain absorbents. The unabsorbed gas is mixed with oxygen (or possibly hydrogen) and burnt; the product of this combustion is again treated with absorbents. If the gas is completely unabsorbed and incombustible it must consist of nitrogen and (or) some member of the argon group. Nitrogen combines with, and so may be removed by, metallic magnesium at a high temperature, or lithium at a low red heat.

### REACTIONS OF GASES.

|                                       |  |
|---------------------------------------|--|
| Acetylene.                            | Absorbed by Br water. Forms brick red ppt. with $\text{Cu}_2\text{Cl}_2$ .   |
| Ammonia.                              | Very soluble in water. Expelled from its aqueous solution on boiling. Absorbed by $\text{H}_2\text{SO}_4$ .                  |
| Boron chloride.                       | Absorbed by water or KOH.  |
| Boron fluoride.                       | Chars paper.   |
| Carbon disulphide.                    | Very soluble in water.   |
| Carbon dioxide.                       | Absorbed by alcoholic KOH.   |
| Carbon monoxide.                      | Absorbed by KOH or soda lime.  |
| Chlorine.                             | Absorbed by $\text{Cu}_2\text{Cl}_2$ in hydrochloric acid or ammoniacal solution.  |
| Cyanogen.                             | Soluble in water. Removed by KOH or mercury.   |
| Cyanogen chloride.                    | Soluble in water (1 vol. dissolves $4\frac{1}{2}$ vols.) alcohol (1 vol. dissolves 23 vols.) and absorbed by moist alkalies. |
| Ethylene.                             | Soluble in water (1 vol. dissolves 25 vols.) more so in alcohol. Absorbed by KOH.  |
| Hydrogen.                             | Absorbed by fuming $\text{H}_2\text{SO}_4$ , Br water, or $\text{Cu}_2\text{Cl}_2$ solution.                                 |
| Hydrogen chloride, bromide or iodide. | Absorbed by palladium.   |
| Hydrogen cyanide.                     | Absorbed by water, KOH, or powdered borax.   |
| Hydrogen phosphide.                   | Absorbed by water, alkalies, or mercuric oxide.  |
| Hydrogen silicide.                    | Slowly absorbed by $\text{CuSO}_4$ soln. Decomposed by Br or fuming $\text{H}_2\text{SO}_4$ .                                |
| Hydrogen sulphide.                    | Decomposed by KOH, 1 vol. giving 4 vols. $\text{H}_2$ .  |
| Methane.                              | Soluble in water and KOH. Darkens lead acetate paper.  |
| Methyl, ethyl amines.                 | Decomposed by Br or conc. $\text{H}_2\text{SO}_4$ .  |
| Methyl chloride.                      | Insoluble in water. Burns with faintly luminous flame.   |
| Methyl ether.                         | See ammonia.   |
|                                       | Soluble in water (1 vol. dissolves 4 vols.) Very soluble in alcohol.   |
|                                       | Soluble in water (1 vol. dissolves 32 vols. at $10^\circ$ ) and $\text{H}_2\text{SO}_4$ ; very soluble in alcohol.           |

|                   |   |
|-------------------|---|
| Nitric oxide.     | Absorbed by Br water or $\text{FeSO}_4$ soln. Combines with oxygen giving nitrogen peroxide, which can then be absorbed by KOH. |
| Nitrous oxide.    | With an equal vol. of hydrogen, gives an explosive mixture, leaving an equal vol. of nitrogen. Soluble in alcohol and water.    |
| Nitrogen.         | Insoluble. Combines at red heat with titanium, magnesium, and lithium.  |
| Oxygen.           | Absorbed by alkaline pyrogallol, phosphorus, cuprous chloride, or sodium hydrosulphite soln.                                    |
| Silicon fluoride. | Absorbed and decomposed by water, with separation of gelatinous silicic acid.   |
| Sulphur dioxide.  | Soluble in water. Absorbed by KOH. dry $\text{PbO}_2$ and $\text{MnO}_2$ .  |

### EXAMINATION OF A GAS.

The gas is tested for colour, smell, and combustibility. It is then sparked, and note is taken of any change in volume, the formation of any coloured gas (e.g.,  $\text{NO}_2$  from nitrogen and oxygen), or of any deposition of carbon, phosphorus, arsenic, sulphur, silica, etc.

A. If the gas is not combustible it is treated with strong potash solution.

I. No appreciable absorption :

(a) Gas ignites a glowing splinter of wood.

Odourless, absorbed by alkaline pyrogallol, or sodium hydrosulphite soln.

Peculiar odour, shows reactions of oxygen, attacks mercury, decomposes potassium iodide.

Odourless, unabsorbed by pyrogallol, fairly soluble in cold water and absolute alcohol.

(b) Gas does not support combustion.

Absorbed by ferrous sulphate solution, gives red fumes when mixed with air.

No positive reactions.

Oxygen.

Ozone.

Nitrous oxide.

Nitric oxide.

Nitrogen.

II. Absorption.

First note whether the gas will dissolve in water alone—ammonia, hydrochloric hydrobromic, or hydriodic acid, boron fluoride, silicon fluoride.

(a) The gas is of a yellow colour, and attacks mercury.

Greenish yellow, strong smell, attacking the mucous membrane.

Yellow, fairly soluble in water, explosive.

Greenish yellow, very explosive.

Chlorine.

Chlorine monoxide

Chlorine dioxide.



**(b) Yellowish red.**

Absorbed by ferrous sulphate solution, conc.  $\text{H}_2\text{SO}_4$ , and by water, with which it forms nitric and nitrous acids, and nitric oxide.

Nitrogen peroxide

**(c) Reddish brown.**

Odour similar to, but stronger than, that of chlorine

Bromine.

**(d) Colourless.**

Strong smelling, reacts alkaline with litmus, very soluble in water, white fumes with hydrochloric acid.

Ammonia.

Sharp smell, reacts acid, soluble in water, turns dichromate paper green.

Sulphur dioxide

Soluble in its own volume of water, gives with lime water a white ppt. soluble with excess of carbon dioxide.

Carbon dioxide

Strong smell, decomposed slowly by water.

Cyanogen chloride

**(e) Colourless, acid reaction, white fumes with ammonia.**

Decomposed by chlorine with separation of iodine or iodine monochloride.

Hydriodic acid.

Decomposed by chlorine with formation of bromine.

Hydrobromic acid.

Not decomposed by chlorine.

Attacks glass.

Absorbed by water with separation of gelatinous silicic acid.

Hydrochloric acid  
Hydrofluoric acid  
Silicon fluoride.

Gives dense fumes in the air, chars paper, very soluble in water, absorbed by turpentine.

Boron fluoride.

**B. The gas is combustible.**

Burns with a scarcely visible blue flame, forming water.

Hydrogen.

Bright blue flame, product carbon dioxide.

Carbon monoxide.

Blue flame, separation of sulphur on cold surface, and formation of acids containing sulphur.

Hydrogen sulphide,  
carbon oxysulphide  
or disulphide.

Red flame, separation of brown selenium.

Hydrogen selenide.

Brilliant yellow flame, formation of phosphoric acid, or deposition of phosphorus, often burns spontaneously.

Phosphine.

Bluish white flame, deposition of white arsenious oxide or brown arsenic.

Arsine.

Red flame, deposition of white silica or brown silicon, often burns spontaneously.

Hydrogen silicide

Faintly luminous flame, formation of water and carbon dioxide.

Methane.



After this test the gas is treated with caustic potash solution.

## I. Absorption.

Soluble in water, can be expelled from solution by warming with potash, gas and solution smell like ammonia, alkaline reaction, dense fumes with hydrochloric acid, and a ppt. with platinic chloride. Methyl and similar amines.

Soluble in water, soluble in alcohol and ether. Methyl ether

Gas dissolves slowly in water:

1. Combustible with blue flame, sulphur and sulphur dioxide resulting, bad odour, ppts. many metals from their salt solutions. Hydrogen sulphide.
2. Bad odour, brown selenium separates on burning. Hydrogen selenide
3. Burns with separation of tellurium. Hydrogen telluride.
4. Burns with purple red flame, no water formed. Cyanogen.

## II. No absorption either by water or caustic potash solution.

Volume of gas quadruples on treatment with potash, burns depositing silica and brown silicon. Hydrogen silicide.

Burns with blue flame, producing carbon dioxide but no water, absorbed by cuprous chloride. Carbon monoxide

Burns forming water only. Hydrogen.

Combustion results in separation of stable body, aqueous solution of which reacts acid; gives black ppt. with copper sulphate:

1. Fishy odour, often spontaneously combustible, giving red phosphorus and phosphorus pentoxide, absorbed by acid cuprous chloride. Phosphine.
2. Peculiar odour, burns to arsenious oxide, and deposits arsenic, absorbed by acid cuprous chloride, giving black ppt. Arsine.

Burns to water and carbon dioxide, sometimes with separation of carbon:

1. Unabsorbed by sulphuric acid, bromine, or ammoniacal cuprous chloride, slightly soluble in absolute alcohol. Paraffin hydrocarbons.
2. Burns with a luminous flame, unabsorbed by cuprous chloride, absorbed by bromine or fuming sulphuric acid. Very slowly absorbed by concentrated sulphuric acid. Ethylene.
3. As ethylene, but easily absorbed by sulphuric acid. Propylene, butylene.
4. Burns with smoky flame, absorbed by bromine, and by ammoniacal cuprous chloride, giving a red ppt. Acetylene.

- |  |  |
|--|--|
| 5. As acetylene, but giving yellow ppt. with cuprous chloride. | Allylene.                                    |
| 6. Burns with green mantled flame.                             | Methyl chloride, ethyl chloride or fluoride. |

## ANALYSIS OF GAS-MIXTURES.

*Correction for temperature and pressure.* See Physico-Chemical Constants section.

### Absorbents

Potash. 400 gm. KOH dissolved in 1 litre of water.  
 Bromine. Dissolved in a 5 per cent. solution of KBr until a fairly deep colour is obtained.  
 Pyrogallol. 10 gms. pyrogallol dissolved in 25 to 30 cc. water. *When required for use* one part of this solution is mixed with five times its volume of potash solution.  
 Cuprous chloride. (i) Ammoniacal. Mix together 50 gm. cuprous chloride and 25 gm. ammonium chloride, add 150 cc. water and pass in ammonia gas, shaking at frequent intervals until solution is complete.  
 (ii) Hydrochloric acid. Dissolve 25 gm. black copper oxide in concentrated hydrochloric acid, add 30 gm. copper, and boil under a reflux condenser until colourless. Dilute to 500 cc. with conc. hydrochloric acid.

## ESTIMATION OF CARBON DIOXIDE AND CARBON MONOXIDE IN AIR.

*Carbon dioxide.* The carbon dioxide from a known volume of air is absorbed by means of a standard baryta solution, and the excess baryta is titrated with oxalic acid, using phenolphthalein as indicator (Pettenkofer).

Required: (i) Soln. of oxalic acid, 5.63 grm. per litre, of which 1 cc. = 1 cc.  $\text{CO}_2$ ; (ii) soln. of 200 grm.  $\text{Ba}(\text{OH})_2$  and 10 grm.  $\text{BaCl}_2$  per litre; (iii) dilute baryta soln. containing 30 cc. of former soln. to 1000 cc. The strength of this last solution is determined by placing in a small flask nearly sufficient oxalic acid to neutralise 10 cc. baryta, then adding the baryta and neutralising by slowly running in more oxalic acid. By this means an accurate standardisation is made possible, as the solution is never so strongly alkaline as to absorb appreciable amounts of carbon dioxide from the air.

For the estimation of carbon dioxide, thick-walled conical Erlenmeyer flasks are used. They are furnished with double.

bored rubber stoppers, the holes in which are closed by short pieces of glass rod. The content of each flask is measured up to the point to which the rubber stopper reaches, and is marked on the outside of the flask. The simplest way of obtaining a sample of the air is to fill a flask with water, and empty it in the room, the air of which is to be tested. By means of a pipette 10 cc. baryta is run into the flask, the glass rods being removed from the holes in the stopper, and the point of the pipette being inserted through one of them. The flask is now stoppered up again, and should be shaken at intervals during half an hour, after which the glass rods are again removed, phenolphthalein is added, and oxalic acid is run in from a burette until the solution is colorless.

The difference between the titrations of fresh baryta and that in the flask gives the carbon dioxide content in cc. (Hesse's Method ; for further details see Hempel, *Gas Analysis*.)

*Carbon monoxide.* In small quantities (less than 1 per cent.) carbon monoxide can only be accurately estimated by means of blood, or by some oxidation method.

(i) Hæmoglobin, the colouring matter of blood, unites with oxygen and carbon monoxide, and the carbon monoxide compound dissociates less readily than the oxy-compound. The proportion of oxy-hæmoglobin to carbon monoxide hæmoglobin will be the ratio of the partial pressures of the gases in the mixture.

If the oxygen content of the air is known, the amount of carbon monoxide can readily be calculated if the proportion between oxy-hæmoglobin and carbon monoxide hæmoglobin in the blood is determined. This can be done colorimetrically, using a solution containing 1 gm. of carmine with a few drops of ammonia in 100 cc. glycerine diluted with water to 1 litre. A dilute solution of oxy-hæmoglobin is yellow, one of carbon monoxide hæmoglobin is rose-red.

A sample of air is taken by filling a flask of 250 cc. capacity with water and emptying it in the room. Now 5 cc. of a 5 per cent. aqueous solution of defibrinated ox-blood is run in, the bottle is stoppered up, and shaken for some minutes. The liquid is then brought into one of three exactly equal test tubes. The second tube contains 5 cc. of blood solution, and the third the same quantity saturated with carbon monoxide. To the first and second tubes carmine solution is added until the solutions have attained the same degree of colour as that of the liquid in the third tube. Then if  $x$  and  $y$  cc. are amounts of carmine solution added to the first and second tubes respectively, and  $S$  is the per cent. saturation

of the blood which was shaken with the air.

$$\frac{x}{x+5} \times \frac{y+5}{y} \times 100 = S$$

From the following table the content of carbon monoxide in the air can be obtained :

|              |       |      |      |      |      |      |      |      |     |
|--------------|-------|------|------|------|------|------|------|------|-----|
| S.           | 10    | 20   | 30   | 40   | 50   | 60   | 70   | 80   | 90  |
| CO per cent. | 0.015 | 0.04 | 0.08 | 0.12 | 0.16 | 0.22 | 0.30 | 0.60 | 1.2 |

If the air contains more than 1 per cent. carbon monoxide the estimation is preferably carried out by absorption with cuprous chloride.

(ii) An oxidation method for the estimation of small quantities of carbon monoxide was described by Kinnicutt and Sandford (*J. Amer. Chem. Soc.*, 1900, 22, [1], 14-18; *J.S.C.I.*, 1900, 19, 275-276).

Good results were obtained by oxidising with iodine pentoxide, and titrating the liberated iodine with N/1000 sodium thiosulphate. The iodine pentoxide was contained in a small U-tube which could be heated to 150°C. by means of an oil-bath. This tube was connected to an absorption tube containing potassium iodide solution, and 250 cc. to 1000 cc. of gas was passed through, unsaturated hydrocarbons, hydrogen sulphide, sulphur dioxide and other reducing gases being removed before coming into contact with the iodine pentoxide. It was found that the presence of other constituents of coal gas had no effect, and the method is available for the determination of 0.0025 per cent. of carbon monoxide in air.

## COAL GAS AND FUEL GASES.

Coal gas consists mainly of hydrogen, carbon monoxide, paraffins, chiefly methane, unsaturated hydrocarbons, vapours of benzene, toluene, etc. In addition there are usually present small quantities of carbon dioxide, oxygen, nitrogen, and sulphur compounds.

The various constituents are determined in the following order: Carbon dioxide by absorption with strong potash solution, benzene and unsaturated hydrocarbons by fuming sulphuric acid, oxygen by alkaline pyrogallol, and carbon monoxide by ammoniacal or hydrochloric acid cuprous chloride. Paraffins, hydrogen and nitrogen if necessary, remain to be determined by eudiometric combustion with excess air or oxygen. The contraction is noted, and the carbon dioxide formed is absorbed by potash. This absorption is equal to the volume of methane, as methane burns forming its own volume of carbon dioxide.

Then if C=contraction, and A=absorption, volume of

methane = A. Contraction due to methane =  $2A$ , so contraction due to hydrogen =  $C - 2A$ , and volume of hydrogen =  $\frac{2}{3}(C - 2A)$ . Nitrogen is obtained by difference.

It should be mentioned that the gas estimated as methane usually contains a small amount of ethane and possibly propane.

Total sulphur is usually determined by the "Referees' Method." A known volume of gas is burned at the rate of about 0.5 cu. ft. an hour in a small Bunsen burner, and the products of combustion together with some ammonia which is evaporated at the same time are passed upwards through a condensing tower filled with glass marbles to break up the stream of gas.

Bromine water or nitric acid may be allowed to trickle over these marbles, and all the sulphur is then obtained as a solution of ammonium sulphate at the bottom of the condenser. Barium chloride is added and the precipitated barium sulphate is filtered, ignited and weighed.

### FIRE-DAMP.

Fire-damp is essentially a mixture of methane with air. Its explosiveness is greatest when the methane amounts to about 9.5 per cent., the oxygen of the air then being just sufficient for the combustion of the methane. Mixtures containing under 5 or over 14 per cent. methane are not inflammable, but are nevertheless dangerous, especially if coal dust is present.

The Grisometer of Coquillon is used for the determination of methane in fire-damp. A measured volume of the gas, after absorption of carbon di- and monoxides, is mixed with a suitable quantity of oxygen, and led either through a thin platinum tube (internal diameter about 1 mm.) heated by a Méker burner, as in some modifications of the Orsat apparatus, or over a spiral of platinum wire heated to redness by an electric current. The gas then burns quietly.

In the Grisometer of Le Chatelier the amount of the gas is measured by observations of the pressure registered on a small manometer, the gas-volume remaining constant, and changes of temperature being avoided by surrounding the burette with a large quantity of water. The combustion tube is also the measuring tube and is connected to a mercury aspirator and a manometer.

Observations are taken of the manometer height  $h$ , barometric height  $H$ , and temperature of water  $t$ , and a flame is

initiated, a known volume of methane being added, if necessary, to make the mixture burn. Height of manometer  $h^1$ , and temperature of water  $t^1$ , are again taken. Then the methane in 100 vols. of gas mixture

$$= \frac{1}{2} \left( \frac{h - h^1}{H + h - h^1} - \frac{t - t^1}{t + 273} \right) \frac{t + 273}{t^1 + 273}$$

or approx.  $\frac{h - h^1}{2(H + h - h^1)}$ .

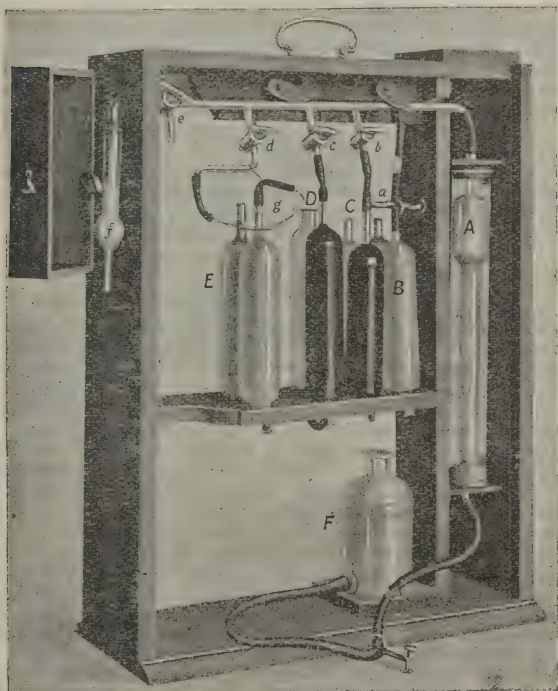
### THE ORSAT APPARATUS.

This apparatus is widely used for the analysis of flue gases, exhaust gases and other similar mixtures. The burette *A*, which has a capacity of 100 cc., is made narrow at the lower end and graduated in  $1/5$  cc. *A* is situated in a glass cylinder containing water and is connected at the bottom to a small levelling bottle by means of a rubber tube. *B*, *C* and *D* are absorption vessels which in order to increase the surface are filled with glass tubes. Each of these bulbs is connected at the lower end with another equally large vessel which serves as a reservoir for the absorbent. The cocks *b*, *c*, *d*, are simple glass cocks which in order to avoid danger of breakage are best connected by means of rubber tubes; *e* is a three way cock, being drilled axially through the stopper in addition to the usual transverse boring. The tube *f* is filled with cotton wool in order to filter any dust from the incoming gas. By simply moving the cock *e* it is possible to connect *f* with *A*, the outer air with *A* or the outer air with *f*.

*B* is filled with caustic potash solution, *C* with alkaline pyrogallol, and *D* with cuprous chloride solution. *E*, which is connected to the capillary main by a platinum tube, contains water or glycerine and water, and is used in the estimation of combustible gases. The cocks *b*, *c*, *d*, are closed, and *A* is connected to the outer air by means of the three-way cock, *e*; by raising the levelling bottle *F*, the burette *A* is filled to the upper mark with water; *e* is then closed, the levelling bottle lowered, and *a* opened. By this means *B* is filled with absorption solution. Similarly *C* and *D* are filled. The tube *f* can now be connected to the sample of gas to be analysed and by turning *e* so as to open to the outer air the tube can be washed with the gas sample by attaching a suction pump to the outlet. The three way cock is now turned to allow the passage of sample to *A*, which is filled with gas by means of the levelling bottle. This process is carried out twice to ensure the removal of air; *e* is then closed, *a* opened, and by means of *F* the gas is forced from *A* into *B*, where the carbon dioxide will be absorbed. The



process is now reversed and the gas returned to *A*. *F*' is now adjusted until the levels of the water in *A* and *F* are the same when the volume of gas may be read on *A*. By subtracting this figure from the original volume (100 cc.) the volume of carbon dioxide absorbed is obtained. By the same means the



absorptions of gas in *C* and *D* yield the volume percentages of oxygen and carbon monoxide respectively. Care must be taken to avoid any of the absorption solutions passing into the horizontal capillary tubes.

For the estimation of methane and hydrogen 10 cc. of the

gas after the removal of absorbable constituents is made up to 100 cc. with air or oxygen. This mixture is passed slowly through the platinum tube *g*, heated to redness by a Méker burner, into the bulb *E*. In order to ensure complete combustion the gas should be passed through the heated platinum tube at least four times. It is then taken back into the burette *A*, and the contraction noted. The carbon dioxide produced by the combustion is estimated by absorption in potash. The amounts of methane and hydrogen can then be calculated as previously explained. Nitrogen is always estimated by difference. If it is required to determine unsaturated hydrocarbons the pyrogallol pipette may be disconnected at the rubber joint and temporarily replaced by one containing bromine water.

It should be remembered that after absorption with bromine water or cuprous chloride in hydrochloric acid the gas *must* be washed with potash before the reading is taken in *A*, as the vapour pressures of these absorbents are considerable.

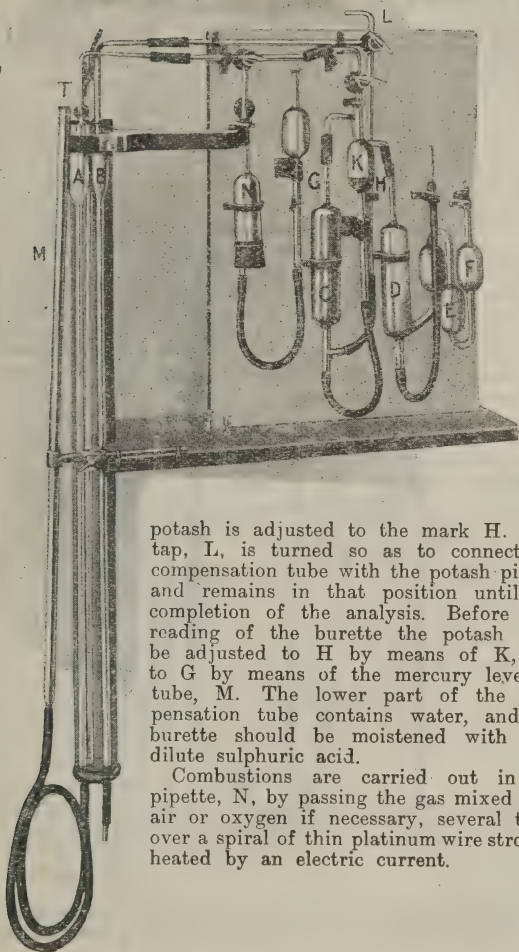
### THE HALDANE APPARATUS.

This apparatus is intended particularly for the analysis of air, but it is also useful for the determination of small quantities of methane or carbon monoxide in mine gases, etc. There are several modifications, full descriptions of which will be found in "Methods of Air Analysis" (J. S. Haldane). The diagram is of the form suited for use in a laboratory.

The gas is measured in the burette, *A*, which is about 800 mm. long. The upper wide part is of about 25 mm. bore, and has a capacity of 15 cc. The narrow part which is of about 3.5 mm. bore, is graduated to 0.01 cc. from 15 to 20 cc. The capacity is measured from the three-way tap, *T*, and does not include the bore. A water-jacket surrounds both the gas-burette and a compensation tube, *B*, the object of the latter being to nullify the effect of any changes of atmospheric pressure or temperature on the burette readings. One of the connections of the three-way tap is used for sampling, and the other is connected with the absorption pipettes, *C* and *D*, usually containing potash solution and alkaline pyrogallol respectively. The pyrogallol is protected from the atmosphere by potash solution in the bulbs, *E* and *F*. Before every burette reading the pressure should be adjusted by bringing the potash level to the mark, *G*, and using the pipette as a pressure gauge.

At the beginning of the analysis the tap, *L*, is opened to the atmosphere and by means of the levelling tube, *K*, and the



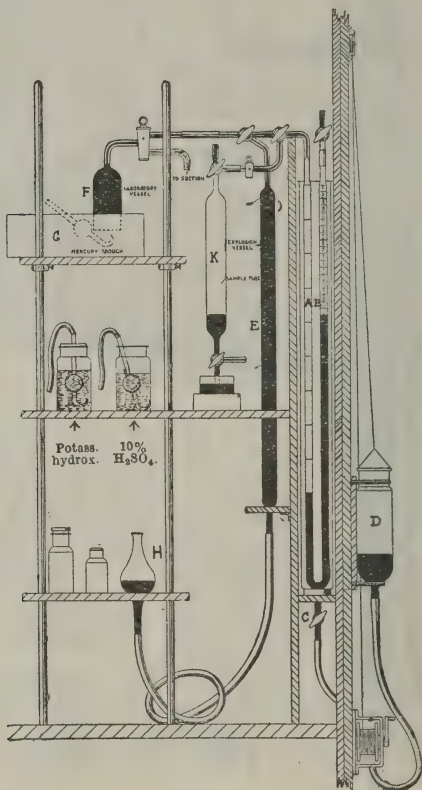


potash is adjusted to the mark H. The tap, L, is turned so as to connect the compensation tube with the potash pipette and remains in that position until the completion of the analysis. Before each reading of the burette the potash must be adjusted to H by means of K, and to G by means of the mercury levelling tube, M. The lower part of the compensation tube contains water, and the burette should be moistened with very dilute sulphuric acid.

Combustions are carried out in the pipette, N, by passing the gas mixed with air or oxygen if necessary, several times over a spiral of thin platinum wire strongly heated by an electric current.

## BONE AND WHEELER APPARATUS.

There are several modifications of this apparatus; the diagram is of the form originally suggested for commercial gas analysis. (*J.S.C.I.*, 1908, **37**, 10.)



The apparatus consists of three main parts : (i) the measuring and pressure tubes, A and B surrounded by a water-jacket, and

connected to the mercury reservoir D; (ii) the explosion tube, E, connected to a separate mercury reservoir, H, and fitted with platinum electrodes and leading wires to an induction coil; (iii) the absorption vessel, F, standing over mercury in a wooden trough, G.

The gas is measured at constant volume, by means of the pressure which it exerts. For this purpose there is a series of "constant volume" marks in the measuring tube, A, each coinciding with a 100 mm. mark on the pressure tube, B.

The inner surfaces of the tubes, A and B, should be kept moist with dilute sulphuric acid. The moistening of A and B with the same liquid automatically eliminates the influence of water vapour on the measurements.

- A small microscope is sometimes attached to facilitate the reading of the mercury level, and to avoid errors of parallax.

The gas for analysis may be introduced into the apparatus by means of the sampling tube, K, or simply from an ordinary test-tube under the wide end of the absorption vessel, F, which has been previously filled with mercury. Before measuring this gas the mercury level should be adjusted to the zero mark in A (by means of the reservoir, D, and the tap, C), and the reading taken in B. If this reading is not zero the necessary correction must be made on the reading of the sample of gas taken. It is very important that the mercury should be at the top of the pressure tube whenever any gas is admitted into the measuring tube.

The amount of gas originally taken should be as large as possible. Absorbable gases are removed in the laboratory vessel, F, 2 to 5 cc. of the absorbent being introduced by means of a suitably shaped pipette from below the surface of the mercury in the trough. After each absorption the gas is returned to the measuring tube, the pressure is read, and the decrease is noted. In the case of cuprous chloride it is more convenient to work with a solution in ammonia than with one in hydrochloric acid, and before taking the reading the gas must be washed with dilute sulphuric acid.

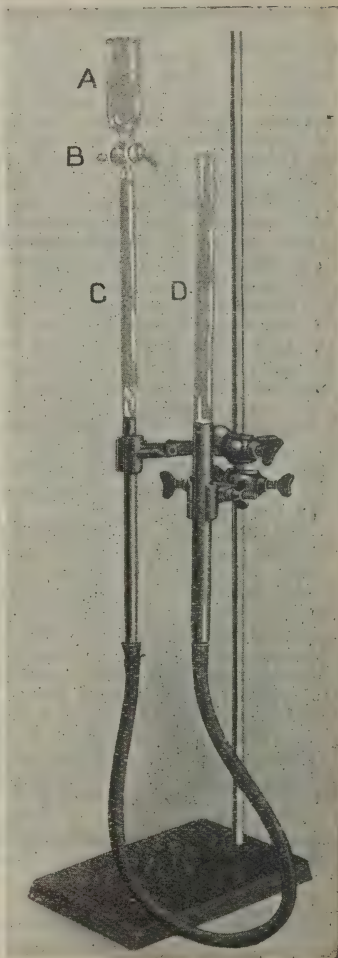
A suitable quantity of the residual gas is then mixed with oxygen or air, and after sparking in the explosion vessel, E, the contraction is noted, and any carbon dioxide formed is absorbed by means of potash.

After the completion of an analysis the whole apparatus should be washed out with sulphuric acid, in order to diminish the possibility of fouling by alkalis.

## The Lunge Nitrometer.

In the nitrometer, nitric acid and nitrates may be estimated by measuring the volume of gas evolved on treatment with concentrated sulphuric acid in presence of mercury. Technically, the nitrometer is most frequently used in estimating the percentage of nitric acid in vitriol or in nitrating mixtures, so that snap samples of a nitrating mixture at various times may serve as a rapid method of estimating the course of a nitration.

The measuring tube C is filled with mercury by means of the levelling tube D, and a quantity of the acid under examination (the amount used being dependent upon the  $\text{HNO}_3$  present) is run into A, and allowed to run into C. The cup A is washed with a further quantity of pure  $\text{H}_2\text{SO}_4$ , which is then run into C, so that the acid in C is approximately 80%  $\text{H}_2\text{SO}_4$ , taking care that no air bubbles pass into C. The tube C is then well shaken until no further gas is liberated, and the apparatus allowed to stand one hour. The mercury levels are adjusted so that the level in D is higher than that in C by an amount equal to  $1/7$ th of the layer of  $\text{H}_2\text{SO}_4$  present in C (to correct for gravity of  $\text{H}_2\text{SO}_4$ ).



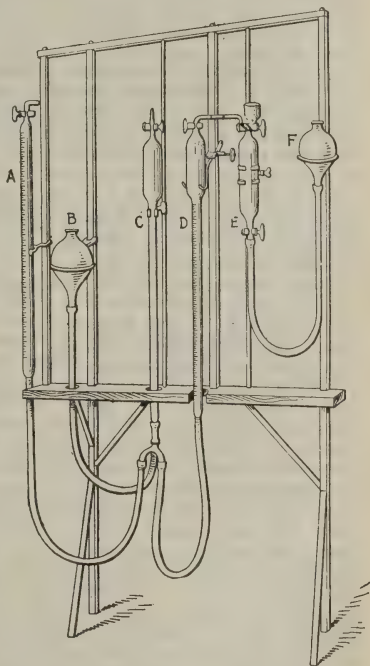
The volume of the gas, the temperature and pressure in the laboratory are taken, and then the gas volume is corrected to  $0^{\circ}$  and 760 mm., and from this the percentage of  $\text{HNO}_3$  may be obtained.

### The Du Pont Nitrometer.

The Du Pont nitrometer, as illustrated, is a more delicate and more convenient apparatus for the volumetric determination of nitric acid or nitrates, and is extensively used in the U.S.A. (see J. R. Pitman, *J.S.C.I.*, 1900, **19**, 982).

The main components are the generating bulb (E) and the mercury reservoir (F), which correspond to the two limbs of the Lunge nitrometer. The generating bulb is connected by means of a two-way tap to the cup or to the measuring chamber (D), which has a volume of 240.4 cc., and is calibrated to read in percentages of nitrogen, being graduated in  $\frac{1}{100}\%$  from 10 to 14%. The measuring burette (A) may be used in place of D in case a wider range of measurement is necessary. It is usually graduated to hold 3.001 milligrams of NO at  $20^{\circ}\text{C}$ . and 760 mm. pressure, and is divided into 100 units (sub-divided into tenths). When compensated, the gas from ten times the molecular weight in milligrams of a nitrite of formula  $\text{RNO}$ , (or five times the molecular weight of  $\text{R}(\text{NO}_3)_2$ ) should exactly fill the burette. From this, the percentage of

nitric acid in a mixed acid is given by the following formula :

$$\frac{63.02 r}{100 w}, \quad \text{where } r \text{ is burette reading, and } w \text{ is weight of mixed acid in grams.}$$


C is a compensating burette similar in form to the chamber D, and B is the levelling bulb and mercury reservoir for A, C, and D.

*Standardisation of the apparatus.*

The most convenient and rapid method of standardisation is as follows:—20–30 cc. of sulphuric acid are drawn into the generating bulb E through the cup, together with about 210 cc. of air. The taps are then closed, and the bulb thoroughly shaken to dry the air, which is then forced over into the compensating chamber C. Exactly 1 gram. of chemically pure potassium nitrate dissolved in 2 to 4 cc. of water is introduced into the generating chamber, and washed in with three or four amounts (total 20 cc.) of pure concentrated sulphuric acid. The mixture is shaken as below, and the generated gas run into the measuring burette A or D. The columns of mercury in the measuring burette and the compensating chamber are balanced, so that the gas in the measuring burette and the compensating chamber are balanced, so that the gas in the measuring burette reads 13.85 ( $= \% \text{N in } \text{KNO}_3$ ). The level of the mercury in C is marked, and the standardisation is completed. (For fuller details, see Scott, "Standard Methods of Chemical Analysis.")

*Method of making the test.*

Such an amount of the nitric acid, mixed acid, or nitrate (in this case, dissolved in 2 to 4 cc. of water) as will generate 172 to 240 cc. of gas is placed in the cup of the generating bulb, and then drawn into the bulb. The cup is rinsed out with three or four amounts (total 20 cc.) of pure concentrated sulphuric acid, each washing being run separately into the generating bulb. The lower tap is left open during this charging, and also while the bulb is shaken well until apparently all the gas is evolved. The shaking is repeated for two minutes with this tap closed, and then the reservoir is lowered until about 60 cc. of mercury remain in the generating bulb. (If too much mercury is left in the bulb, a long time will be required for the residue to settle, and some gas may be held in suspension by the mercury, leading to inaccurate results.) The generated gas is transferred to the reading burette D, and after cooling for a few minutes, both burettes are balanced, so that the mercury in the compensating burette is level with the standardising mark as well as with the column in the reading burette; the reading is then taken.

If exactly 1 gram. has been used, the reading will give percentage of nitrogen. For other amounts, the reading divided by weight used gives percentage of nitrogen, whilst percentage of nitrogen, multiplied by 4.5 gives percentage of nitric acid.

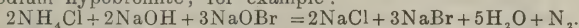


Whenever it is not practicable to produce between 172 and 240 cc. of gas, the measuring burette A should be used, together with the formula under description of the apparatus.

The procedure may be used to estimate nitrites as well as nitrates.

## Ammonium Salts by the Hypobromite method.

Ammonium salts are decomposed by an alkaline solution of sodium hypobromite; for example:



If the reaction takes place in a nitrometer, the nitrogen liberated may be measured.

Wt. of 1 cc. pure nitrogen at N.T.P. = 0.0012507 grm.

The hypobromite solution is prepared from 100 grm. of caustic soda solution (Sp. Gr. 1.1) and 4 grm. of bromine.

To correct for the solubility of nitrogen in the hypobromite solution, 2.5 per cent. of the volume of nitrogen found is to be added (Lunge).

## Factors for Conversion of Volumes of Gas.

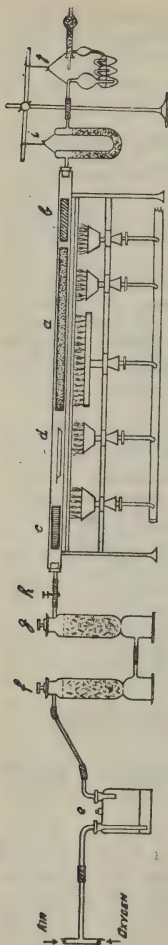
| Substance                  | Method                           | Gas             | 1 cc. (N.T.P.) = mgrm.  |
|----------------------------|----------------------------------|-----------------|---|
| Organic compds.            | Dumas                            | N <sub>2</sub>  | 1.2507 N <sub>2</sub>   |
| Chile saltpetre            | Nitrometer                       | NO              | 3.795 NaNO <sub>3</sub>   |
| Nitrosyl<br>sulphuric acid | „                                | NO              | $\left\{ \begin{array}{l} 1.697 \text{ N}_2\text{O}_8 \\ 2.813 \text{ HNO}_3 \\ 3.795 \text{ NaNO}_3 \end{array} \right.$ |
| Nitroglycerin              | „                                | NO              | 3.379 C <sub>3</sub> H <sub>5</sub> (NO <sub>3</sub> ) <sub>3</sub>   |
| Pyrolusite                 | By H <sub>2</sub> O <sub>2</sub> | O <sub>2</sub>  | 3.880 MnO <sub>2</sub>  |
| Bleaching powder           | „                                | O <sub>2</sub>  | 1.583 Cl <sub>2</sub>   |
| KMnO <sub>4</sub>          | „                                | O <sub>2</sub>  | 0.7143 O <sub>2</sub>   |
| Carbonates                 | Decomp. HCl.                     | CO <sub>2</sub> | 4.468 CaCO <sub>3</sub>   |

## ULTIMATE ORGANIC ANALYSIS.

### Carbon and Hydrogen.

When it is necessary to find the quantitative ultimate composition of an organic substance, the analysis is made by means of a combustion.

A known weight of the substance is burnt in a tube containing copper oxide, the water and carbon dioxide evolved being collected; from the weight of these products the hydrogen and carbon in the substance may be calculated. The oxygen is generally determined by difference, as no satisfactory method for the estimation of oxygen in organic compounds is available.



The apparatus employed is shown in the accompanying diagram, the combustion taking place in a hard glass tube (about 30 inches long), which is heated by means of a special combustion furnace. The space *a* contains granulated copper oxide; *b* is a spiral of copper gauze employed to decompose any oxides of nitrogen formed by combustion; if the substance is known to be free from nitrogen, this may be omitted. The front end of the tube is empty to allow the insertion of the boat *d*. Next to the boat is placed a spiral of copper gauze, previously oxidised by heating to redness in the presence of air or oxygen, in order to prevent the volatile and gaseous products from diffusing backwards along the tube. Arrangements are made to allow the passage of both air and oxygen through the tube, both being previously passed through the same purifying devices *e*, *f*, and *g*. *e* is a wash-bottle containing concentrated sulphuric acid to remove dust and water; *f* and *g* are towers filled with sticks of caustic potash. Between *g* and the tube is a screw clip *h* to allow regulation of the rate of flow of the oxygen or air. At the far end of the combustion tube are connected a calcium chloride tube (*i*) for the absorption of water and potash bulbs (*j*) for the retention of carbon dioxide. In case no calcium chloride tube is attached to the potash bulbs it is necessary to employ a further U-tube packed with calcium chloride or soda lime to collect any moisture which the gases may have absorbed from the potash solution (40% KOH). This latter vessel is always weighed together with the bulbs. Previous to making an estimation, the apparatus should be carefully examined to ensure that all joints are completely gas-tight. The air and oxygen required may be contained in gas-holders.



The method of procedure is as follows: The tube is first heated for a period of one hour to remove completely dust and moisture, after which the front end is allowed to cool and the boat removed. 0.15 to 0.25 gm. of substance is weighed into the boat, and then the calcium chloride tube and potash bulbs are weighed and connected.\*

The boat is now inserted in the tube and the diffusion spiral *c* returned. A current of air (about one bubble per second) is passed through the tube and the diffusion coil heated. When the coil *c* has attained a dull red heat, the boat is slowly heated. After the entire tube has become hot the air supply may be replaced by oxygen for a period of about one hour to ensure the complete combustion of all carbonised residue, after which the air supply is again connected, until the whole of the apparatus is filled with air. The calcium chloride tube and potash bulbs may now be disconnected and allowed to cool previous to weighing. The increase in weights of the calcium chloride tube and the potash bulbs show the yield of water and carbon dioxide respectively.

By multiplying the water yield by  $2/18$  ( $H_2/H_2O$ ) the hydrogen content of the substance is obtained. Similarly the carbon content is calculated by multiplying the carbon dioxide yield by  $12/44$  ( $C/CO_2$ ). The entire analysis requires a period of about four hours.

With substances containing sulphur the tube should be filled with lead chromate instead of copper oxide in order to retain the sulphur dioxide which is formed.

### *Halogens, Sulphur and Phosphorus.*

Halogens may be estimated by the Carius method, which consists of heating the substance with a small quantity of concentrated nitric acid in the presence of silver nitrate. By this means the carbon and hydrogen are oxidised and the halogens form insoluble silver salts which can be estimated gravimetrically. The estimation is carried out in a sealed glass combustion tube, which is heated in a tube furnace provided

---

\* If nitrogen or halogens are present in the substance, it will be necessary to reduce the copper spiral *b* by heating to redness and immersing in methyl alcohol vapour in a test-tube, removing the methyl alcohol by heating the spiral to about  $200^\circ C$ .

with wrought-iron pipes, inside which the heating may take place, thus minimising any danger from bursting.

Sulphur may be estimated either by fusion and precipitation (as  $\text{BaSO}_4$ ), or by oxidation with concentrated nitric acid by the Carius method (omitting the silver nitrate) and precipitation. Phosphorus may be oxidised by the Carius method, after which the estimation may be completed in the usual way.

## Volumetric Determination of Nitrogen. (Dumas).

A combustion tube 70 cm. long is filled in the following order: at the sealed end of the tube is placed a layer of 10 cm. of fragments of magnesite, held in position by a loose plug of asbestos, then a layer of 10 cm. of granular copper oxide, followed by 0.3–0.6 grm. of the substance and powdered copper oxide, then a layer of 40 cm. of granular copper oxide, and finally a roll 10 cm. long of copper gauze.

The end half of the magnesite is heated to replace the air in the tube by carbon dioxide. When this process is complete the gas evolved is completely soluble in caustic potash solution. This solution is contained over mercury in a volumenometer, provided with a levelling tube. The combustion is then made as usual, and the nitrogen evolved collected over the caustic potash solution. The remainder of the nitrogen is driven into the volumenometer by heating the remainder of the magnesite. After levelling, the temperature and volume of the gas and the barometric pressure are noted.

$$\% \text{ N} = \frac{V (b-f)}{760 (1 + \frac{1}{273} t)} \times \frac{28.02}{22403} \times \frac{100}{W} = K \times \frac{V (b-f)}{W}$$

where  $V$  = Volume of nitrogen in cc. at  $t^\circ\text{C}$ . and barometric pressure  $b$  mm.

$f$  = Vapour pressure of the caustic potash (Sp. Gr. 1.29) used at  $t^\circ\text{C}$ . (See Physico-Chemical Constants.)

and  $W$  = Weight of substance used.

Table giving Values of  $K \left( = \frac{100}{760(1 + 1/273 t)} \times \frac{28.02}{22403} \right)$

| °C. | K          | °C. | K          | °C. | K          |
|-----|------------|-----|------------|-----|------------|
| 0   | 0.00016457 | 11  | 0.00015819 | 22  | 0.00015230 |
| 1   | 16397      | 12  | 15764      | 23  | 15178      |
| 2   | 16337      | 13  | 15709      | 24  | 15127      |
| 3   | 16278      | 14  | 15654      | 25  | 15076      |
| 4   | 16219      | 15  | 15600      | 26  | 15026      |
| 5   | 16161      | 16  | 15546      | 27  | 14976      |
| 6   | 16103      | 17  | 15492      | 28  | 14926      |
| 7   | 16045      | 18  | 15439      | 29  | 14877      |
| 8   | 15988      | 19  | 15386      | 30  | 14828      |
| 9   | 15931      | 20  | 15334      | 31  | 14779      |
| 10  | 15875      | 21  | 15282      | 32  | 14730      |

## Determination of Nitrogen. (Kjeldahl).

### *Kjeldahl method.*

0.2—2.0 gram. of the substance (such a quantity should be taken that the nitrogen content is equivalent to about 40 cc. of the standard acid), together with 0.7 gram. of mercuric oxide, or its equivalent in metallic mercury, and 20—30 cc. of concentrated sulphuric acid, are weighed into a long-necked resistance (Kjeldahl) flask. The flask and contents are then heated for a time below the boiling-point of the acid, until all frothing has ceased. Excessive frothing may be overcome by the addition of a small piece of paraffin wax. The heating is increased until the acid boils, and boiling continued until the acid is colourless, or almost colourless, so that further heating causes no more decrease in colour.

After cooling, the acid is diluted with approximately 200 cc. of water, and to this are added a few pieces of granulated zinc or pumice stone, if necessary to prevent bumping, and 100 cc. of potassium sulphide solution (40 gram. commercial potassium sulphide per litre). Approximately 100 cc. of 30% sodium hydroxide solution (sufficient to make the mixture strongly alkaline) are poured carefully down the side of the flask, so as to avoid immediate mixing, and the flask connected to the distillation apparatus, which consists of the distillation flask, bulb-trap to prevent the sodium hydroxide being carried

over mechanically, condenser, and an adaptor, of which the lower end dips under the surface of the liquid in the receiving flask. This consists of a measured quantity of standard acid (say 50 cc.). The distillation flask is shaken to mix the contents thoroughly, and approximately 150 cc. distilled over into the standard acid, excess of which is titrated by means of standard alkali, using cochineal or methyl red as indicator.

0.1—0.3 gm. of copper sulphate crystals may be used in addition to, or in place of, the mercury; in such case, the final colour after boiling would be pale-green. In case mercury or mercuric acid is not used, the use of potassium sulphide is unnecessary.

Particular care should be taken that all reagents are free from nitrogen compounds, and they should be tested by means of a blank experiment on pure cane sugar.

N/2 acid and alkali are generally used, but in determining small amounts of nitrogen, N/10 acid and alkali should be used. The strength of the standard acid should be determined gravimetrically; sulphuric as barium sulphate, hydrochloric as silver chloride; and the alkali standardized against this.

The Kjeldahl method is not available for nitro-, nitroso-, azo- or diazo-compounds, or for hydrazines, nitrates or nitrites, without further modification.

#### *Kjeldahl-Gunning method.*

0.2—2.0 gm. of the substance, together with 10 gm. of powdered potassium sulphate or 10 gm. of anhydrous sodium sulphate, and approximately 20 cc. of concentrated sulphuric acid, are treated exactly as in the Kjeldahl process, except that after dilution, no potassium sulphide is added. 0.1—0.3 gm. of copper sulphate crystals may be added to the mixture.

#### *Kjeldahl-Gunning-Arnold method.*

0.2—2.0 gm. of the substance, together with 15—18 gm. of potassium sulphate (or anhydrous sodium sulphate), 1 gm. of copper sulphate, 1 gm. of mercuric oxide, or its equivalent in metallic mercury, and 25 cc. of concentrated sulphuric acid, are heated gently in a Kjeldahl flask until frothing subsides, and then boiled until the mixture is colourless or practically so. The mixture is cooled, diluted with 200 cc. of water, 50 cc. of potassium sulphide added, made strongly alkaline with sodium hydroxide solution, and distilled as in the original Kjeldahl method.

*Kjeldahl Method modified to include the Nitrogen of Nitrates.*

0.2—2.0 gm. of the substance is placed in a Kjeldahl flask, and to this are added—

(a) 30 cc. of concentrated sulphuric acid containing 1 gm. of salicylic acid, the whole shaken, allowed to stand for 30 minutes, 5 gm. of sodium thiosulphate crystals added, and digested as below; or

(b) 30 cc. of concentrated sulphuric acid containing 2 gm. of salicylic acid, allowed to stand 30 minutes, and then gm. zinc dust added gradually with shaking, and digested as follows :—

The mixture is heated gently until all danger from frothing over has passed, and then boiled until white fumes no longer escape from the flask, which takes about 5—10 minutes. Approximately 0.7 gm. of mercuric oxide is added, or its equivalent in mercury, and then the boiling is continued until the acid is practically colourless. 10 cc. of acid should be added to prevent the material becoming solid in the flask, and the determination completed as in the original Kjeldahl method.

The above methods are substantially the Official Methods of the Association of Official Agricultural Chemists of the U.S.A.

---

# ELECTRO-CHEMICAL ANALYSIS.

## *Sources of Electrical Energy, etc.*

The sources available for electro-deposition are accumulators, Gölcher thermopiles, Bunsen cells, etc., but the first-named are invariably used for electrochemical analysis.

In order to obtain a satisfactory deposit, it is necessary to work at a suitable current density,

C.D. = amperes per square decimetre.

The current is adjusted by means of a rheostat.

$$C = \frac{E - e}{R}$$

where C = Current in amperes, +

E = Main voltage,

e = Back E.M.F. in volts,

R = Resistance in ohms.

## *Apparatus.*

A platinum dish may be employed as cathode, but this is much more expensive than the equally serviceable gauze cylinder or flag electrode.

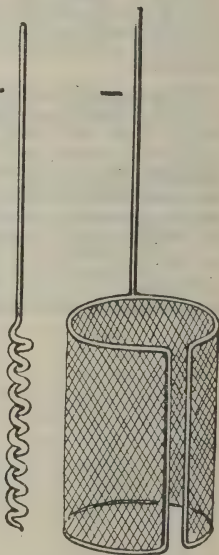
The anode may be a cylinder, or, preferably, a piece of thick platinum wire coiled concentrically, the current being conducted by a portion of the wire bent vertically to the circle.

Platinum basins must not be heated direct, but should be heated on a water-bath.

For antimony, bismuth, mercury, and lead dioxide and manganese dioxide, a roughened gauze cathode is most satisfactory, but should not be finer than 70-80 meshes per sq. cm.

More rapid working is effected by the use of rotating electrodes. A suitable cathode for this purpose, for which a higher C.D. may be used, is a small sand-blasted cylinder of platinum gauze. It is more satisfactory to have a stationary cathode in the form of a platinum gauge cylinder, and to rotate rapidly the anode, which may be a spiral of iridio-platinum.

To prevent loss of liquid by spurting, due to liberation of gas, the containing vessel is covered with a watch-glass, pierced by a hole through which passes the thick vertical platinum wire which carries current to the anode.





The electrolysis is continued until a drop of the liquid on testing is found to be free from the metal which is being deposited. The current is discontinued when any liquid which would dissolve the deposit has been replaced by a syphoning arrangement. The cathode is then washed with water, alcohol, and ether, and then dried for a short time at  $100^{\circ}\text{C}$ ., a higher temperature being necessary in the case of dioxide deposits.

In the following, several methods are outlined which have been suggested for electrochemical analyses and separations :

#### *Antimony.*

The precipitated antimony sulphide is dissolved in 80 cc. of saturated sodium sulphide solution ( $\text{Na}_2\text{S}$ ). At ordinary temperature : C.D. = 0.3 ampere ; E.M.F. 1.5 volts.

At  $50^{\circ}\text{C}$ . : C.D. = 1 ampere ; E.M.F. = 2 volts.

The addition of 1 gm. potassium cyanide is an advantage, as it prevents formation of polysulphides.

#### *Cadmium.*

(1) A moderate excess of potassium cyanide is added to a solution containing 0.5 gm. of cadmium, preferably as sulphate or acetate.

C.D. = 0.6 ampere ; E.M.F. = 4.6 volts at ordinary temperature.

C.D. = 0.2 ampere ; E.M.F. = 4 volts at  $50^{\circ}\text{C}$ .

(2) 3 gm. of ammonium sulphate, acetate or formate are added to the cadmium solution, and then 1 cc. of a 20 per cent. solution of the corresponding free acid.

C.D. = 0.2 ampere ; E.M.F. = 2.5 volts at  $60^{\circ}\text{C}$ .

#### *Copper.*

(1) In absence of chlorides, bismuth, arsenic, antimony, tartaric and citric acids. To the solution of nitrate or sulphate, 5 per cent. of concentrated nitric acid is added.

C.D. = 1 ampere ( $\frac{1}{2}$  ampere if other metal present) ; E.M.F. = 2.5 volts. It is preferable to warm the solution to  $50^{\circ}\text{C}$ . and to use stirring apparatus. The final solution is gradually syphoned off and replaced by water before breaking the current. When most of the copper has been deposited, about 0.5 gm. urea should be added to decompose any nitrite which may have been formed as this prevents complete deposition of copper.

(2) Potassium cyanide is added in slight excess until the yellow ppt. first produced has dissolved.

C.D. = 1 ampere ; E.M.F. = 5-6 volts (4-5 volts in warm solutions). About two hours are required for complete deposition.

*Gold.*

(1) If strongly acid the gold solution is almost neutralised with caustic potash. 2 grm. of pure potassium cyanide added to convert into the auricyanide.

At ordinary temperature: C.D. = 0.25 ampere; E.M.F. = 3 volts.

At 50°C.: C.D. = 0.7 ampere; E.M.F. = 3 volts.

(2) 30 cc. of saturated sodium sulphide solution are added, and the solution electrolysed at the ordinary temperature.

C.D. = 0.2 ampere; E.M.F. = 2 volts.

(3) 6 grm. of ammonium thiocyanate are dissolved in 60 cc. water, the solution warmed to 50°C., and the gold solution added with constant stirring.

At ordinary temperature or 50°C.: C.D. = 0.3 ampere; E.M.F. = 1.5 volts.

*Iron.*

The ferrous or ferric chloride or sulphate solution containing about 1 grm. of iron is almost neutralised with ammonia and poured into a concentrated solution of 6 grm. of crystallised ammonium oxalate, 5 cc. of a saturated solution of borax added, and the solution warmed.

C.D. = 0.6-1 ampere; E.M.F. = 3.5 volts.

*Lead.*

A sand-blasted platinum dish or, preferably, gauze flag anode, roughened by a sand-blast, is used. The nitrate solution, containing 1 grm. of lead, should be free from silver and chlorine compounds. 20 per cent. of concentrated nitric acid is added.

C.D. = 0.5 ampere; E.M.F. = 2 volts at ordinary temperature.

In case metallic lead separates at the cathode, more nitric acid is added.

The deposit of lead dioxide is dried at 200°C.

*Manganese.*

A roughened anode must be used. To the manganese sulphate solution (containing 0.15 grm. manganese) are added 10 grm. ammonium acetate and 2 grm. of chrome alum (Engels, *Zeitschr. f. Elektrochem.*, 2, 413), and the solution warmed to 75°C.

C.D. = 0.6 to 0.9 amperes; E.M.F. = 3.5 volts.

The deposit is washed, dried, and ignited to  $Mn_2O_4$ , which is then washed and reignited.

*Mercury.*

(1) 2 per cent. of nitric acid is added (5 per cent. in



presence of other metals), and the solution warmed to  $50^{\circ}\text{C}$ .

C.D. = 1 ampere (0.5 ampere in presence of other metals);  
E.M.F. = 4.0 volts. The cathode should be roughened.

(2) 1 per cent. of hydrochloric or sulphuric acid is added.

C.D. = 0.5–0.8 amperes (raised to 1 ampere towards end);  
E.M.F. = 3.5 volts.

The deposit must be dried in a dessicator, as alcohol loosens the globules.

### *Nickel or Cobalt.*

The nickel sulphate solution (free from nitric acid) is added to a mixture of a concentrated solution of 5 grm. of ammonium sulphate and 30–40 cc. of concentrated ammonia solution (for 1 grm. nickel). The solution is stirred, but the deposition is carried out in the cold with C.D. = 1 ampere.

The process for cobalt is identical.

### *Silver.*

3–4 grm. of pure potassium cyanide are added to the solution containing 0.5 grm. of silver.

C.D. = 0.3 ampere; E.M.F. 3.5 volts at ordinary temperature.

C.D. = 0.6 ampere; E.M.F. 5.6 volts at  $50^{\circ}\text{C}$ .

### *Tin.*

If present in sodium sulphide solution, 20 grm. of pure ammonium sulphate are added, and the solution warmed until no more hydrogen sulphide is evolved, and then boiled for several minutes.

An excess of yellow ammonium sulphide is added to a solution containing 0.4 grm. tin, and the solution warmed to  $50^{\circ}\text{C}$ .

C.D. = 1 ampere (gradually reduced to 0.3 ampere);  
E.M.F. = 3.5 volts.

The electrolysis is continued until addition of an excess of hydrochloric acid gives a precipitate of pure sulphur.

### *Zinc.*

Electrodes of nickel, or platinum coated with copper, are used. 4 grm. of potassium oxalate and 3 grm. of potassium sulphate are added to the neutral zinc sulphate or nitrate solution (0.3 grm. of zinc). The deposition is carried out with stirring in the cold.

C.D. = 0.5 ampere; E.M.F. = 4 volts.

After a short time, a few cc. of a 5 per cent. oxalic acid solution are added.

## Electrolytic Separations.

### *Separation of Antimony and Tin.*

The mixture of sulphides (0.5 grm. metal) is dissolved in 80 cc. of a saturated solution of sodium sulphide, 2 grm. of caustic soda added, and the solution warmed to 60°C. The antimony is deposited; C.D. = 0.5 ampere

After the antimony has been removed, the solution is boiled for 15 minutes with 25 grm. of ammonium sulphate. After cooling to 60°C., the solution is electrolysed; C.D. = 1.0 ampere.

### *Separation of Copper and Iron.*

2 per cent. of sulphuric acid is added to a solution of the sulphates, and the warm solution electrolysed with C.D. = 1 ampere. After all the copper has been deposited, the cathode is removed and replaced by a fresh electrode. A solution containing 4 grm. of ammonium oxalate is added, the solution neutralised by suitable additions of ammonia or oxalic acid, heated to 50°C., and electrolysed with C.D. = 1 ampere.

### *Separation of Copper and Lead.*

The anode used is a roughened flag electrode, a wire (bent as usual for an anode) being employed as cathode. 10 per cent. of concentrated nitric acid is added, and the solution warmed to 60°C.

C.D. = 1.5 amperes; E.M.F. = 1.5 volts.

The anode (on which lead dioxide has been deposited) is replaced by a fresh electrode to act as cathode in the electro-deposition of the copper, the current being reversed.

### *Separation of Copper and Silver.*

The method used depends upon the variation of the E.M.F. in nitric acid or cyanide solution.

(1) In nitric acid solution, the silver is deposited first at below 1.3 volts.

(2) In cyanide solution, an excess of 4 grm. of potassium cyanide is used, and the silver is deposited first at below 1.6 volts. Before depositing the copper, sulphuric acid is added in the fume cupboard to decompose part of the potassium cyanide.

### *Separation of Copper and Zinc.*

The copper is deposited from nitric acid solution, and the solution remaining evaporated with sulphuric acid before depositing the zinc in oxalic acid solution.

### *Separation of Lead and Silver.*

10 cc. of concentrated nitric acid are added, the solution heated to  $80^{\circ}\text{C}.$ , and electrolysed, using C.D. = 0.15 ampere. Silver is deposited on the cathode and lead dioxide on the anode.

### **Removal of deposits.**

*Antimony*, by a mixture of nitric and tartaric acids.

*Cobalt*, by warming with concentrated nitric acid.

*Gold*, by warming with potassium cyanide solution to which has been added several cc. of hydrogen peroxide.

*Iron*, by warming with dilute sulphuric acid.

*Lead dioxide*, by warming with a mixture of glucose and nitric acid (1 : 1), or by adding dilute nitric acid and placing a piece of zinc or copper foil in contact with the electrode to form a galvanic couple.

*Manganese oxide* ( $\text{Mn}_2\text{O}_3$ ), by warming with concentrated hydrochloric acid.

*Mercury*, by heating in a Bunsen flame.

*Nickel*, by warming with nitric or sulphuric acid, taking great care that all the deposit has been dissolved before heating the platinum electrode, as nickel tends to become "passive."

*Silver*, by potassium cyanide solution.

*Tin*, by boiling with concentrated hydrochloric acid, or by covering with dilute sulphuric acid and making anode with copper wire as cathode.

*Zinc*, by warming with a strong solution of caustic soda.

# SPECTRUM ANALYSIS.

## Flame Spectra.

Care must be taken to adjust the spectroscope so that the flame visible is above the blue cone; otherwise the green and blue bands of the carbon spectrum of the flame may interfere. The more characteristic lines in each spectrum are denoted by Greek letters. (See Diagram on next page.)

The wave-lengths ( $\lambda$ ) are given in  $\mu\mu$ .

Taking Na = 50 on the scale of the spectrometer :

|                                    |   |   |     |
|------------------------------------|---|---|-----|
| K $\alpha$ is at scale division 17 |   |   |     |
| Li $\alpha$                        | " | " | 32  |
| Tl                                 | " | " | 68  |
| Sr $\delta$                        | " | " | 106 |
| ln $\alpha$                        | " | " | 111 |
| ln $\beta$                         | " | " | 149 |
| K $\beta$                          | " | " | 154 |
| H                                  | " | " | 162 |

*Sodium.* Golden-yellow line at  $\lambda 589\cdot3$  (D line); with fairly powerful spectroscope double line at  $\lambda 589\cdot6$  and  $\lambda 589\cdot0$ .

*Potassium.* Red double line ( $\alpha$ ) at  $\lambda 769\cdot9$  and  $\lambda 766\cdot5$ ; violet line ( $\beta$ ) at  $\lambda 404\cdot4$ .

*Lithium.* Red line ( $\alpha$ ) at  $\lambda 670\cdot8$ ; faint golden-yellow line ( $\beta$ ) at  $\lambda 610\cdot3$ .

*Rubidium.* Violet double line ( $\alpha$  and  $\beta$ ) at  $\lambda 420\cdot2$  and  $\lambda 421\cdot5$ ; red double line ( $\gamma$  and  $\delta$ ) at  $\lambda 781\cdot1$  and  $\lambda 795\cdot0$ .

*Cæsium.* Blue double line ( $\alpha$  and  $\beta$ ) at  $\lambda 455\cdot5$  and  $\lambda 459\cdot3$ .

(Rubidium and cæsium must be separated from large amounts of potassium and sodium salts, by fractional crystallisation of the acid oxalates, etc.)

*Calcium.* Golden-yellow band ( $\alpha$ ) at  $\lambda 620\cdot3$  to  $\lambda 618\cdot2$ ; yellowish-green band ( $\beta$ ) at  $\lambda 554\cdot4$ .

*Strontium.* Red or golden-yellow bands are produced at  $\lambda 686\cdot3$ ,  $\lambda 674\cdot4$  ( $\beta$ ),  $\lambda 662\cdot8$  ( $\gamma$ ),  $\lambda 649\cdot9$ ,  $\lambda 646\cdot5$ ,  $\lambda 635\cdot1$ ,  $\lambda 606\cdot0$  ( $\alpha$ ); blue line ( $\delta$ ) at  $\lambda 460\cdot7$ .

*Barium.* Green line ( $\alpha$ ) at  $\lambda 553\cdot5$ ; green bands at  $\lambda 534\cdot7$  ( $\gamma$ ),  $524\cdot3$  ( $\delta$ ),  $513\cdot7$  ( $\beta$ ),  $500\cdot0$ ; blue band at  $487\cdot4$ .

*Calcium, strontium, and barium* in admixture. Only the following are characteristic :

*Calcium* : golden-yellow band ( $\alpha$ ).

*Strontium* : golden-yellow band ( $\alpha$ ); blue line ( $\delta$ ).

*Barium* : green bands ( $\beta$ ,  $\gamma$ , and  $\delta$ ).

*Thallium.* Green line at  $\lambda 535\cdot 0$ .

*Indium.* Blue line at  $\lambda 451\cdot 1$ ; violet line at  $\lambda 410\cdot 1$ .

*Copper.* Green lines at  $\lambda 550\cdot 7$  and  $\lambda 538\cdot 6$ ; blue bands at  $\lambda 443\cdot 7$  to  $\lambda 441\cdot 3$  and  $\lambda 435\cdot 4$  to  $\lambda 433\cdot 2$ ; continuous spectrum in yellow and green.

*Manganese.* Two golden-yellow bands; four green bands of which  $\lambda 559\cdot 2$ ,  $\lambda 539\cdot 2$  and  $\lambda 515\cdot 8$  are characteristic.

*Boric acid.* Four golden-yellow and yellow bands; two green bands; two blue bands. Yellow band at  $\lambda 548\cdot 1$  to  $\lambda 544\cdot 0$  and green bands at  $\lambda 519\cdot 3$  and  $\lambda 491\cdot 2$  are characteristic.

## Spark Spectra.

Only the wave lengths of the stronger lines are mentioned.

*Iron.* Green lines at  $537\cdot 0$ ,  $532\cdot 6$ ,  $526\cdot 6$ ,  $523\cdot 2$ ,  $519\cdot 2$ ,  $516\cdot 8$ ,  $513\cdot 9$ ,  $495\cdot 9$ ,  $492\cdot 3$ ; blue lines at  $489\cdot 1$ ,  $487\cdot 4$ .

*Nickel.* Green lines at  $547\cdot 7$ ,  $508\cdot 1$ ; blue line at  $471\cdot 5$ .

*Cobalt.* Green lines at  $535\cdot 3$ ,  $534\cdot 0$ ,  $528\cdot 0$ ,  $526\cdot 7$ .

*Chromium.* Green line at  $520\cdot 7$ ; blue lines at  $429\cdot 0$ ,  $427\cdot 5$ ,  $425\cdot 4$ .

*Manganese.* Golden-yellow line at  $601\cdot 7$ ; blue lines at  $482\cdot 4$ ,  $478\cdot 4$ ,  $476\cdot 6$ ,  $475\cdot 4$ .

*Zinc.* Golden-yellow line at  $536\cdot 6$ ; blue lines at  $481\cdot 0$ ,  $472\cdot 2$ ,  $468\cdot 0$ .

*Cadmium.* Red line at  $643\cdot 9$ ; green line at  $508\cdot 6$ ; blue lines at  $480\cdot 0$  and  $467\cdot 8$ .

*Magnesium.* Green line at  $518\cdot 3$ .

*Antimony.* Golden-yellow line at  $600\cdot 5$ ; green line at  $556\cdot 8$ .

*Bismuth.* Green line at  $555\cdot 2$ ; blue line at  $472\cdot 4$ .

*Lead.* Green line at  $500\cdot 5$ ; violet line at  $405\cdot 8$ .

*Mercury.* Green line at  $546\cdot 1$ ; blue line at  $435\cdot 8$ .

*Tin.* Yellowish-green line at  $563\cdot 2$ ; blue line at  $452\cdot 5$ .

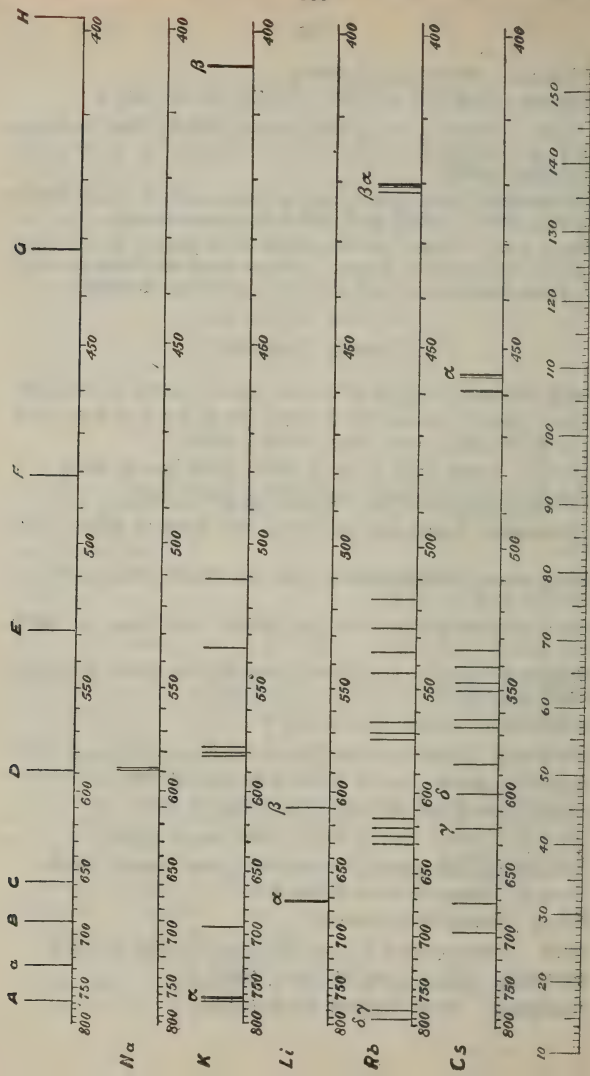
*Copper.* Green lines at  $521\cdot 8$ ,  $515\cdot 3$ .

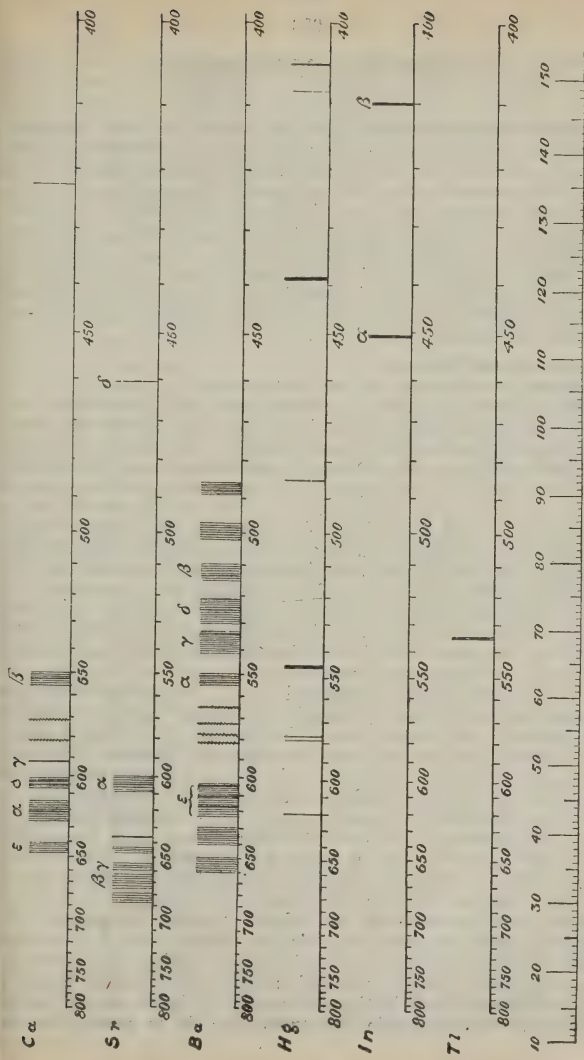
*Silver.* Green line at  $546\cdot 5$ .

*Gold.* Golden-yellow line at  $627\cdot 8$ ; yellow line at  $583\cdot 7$ .

*Platinum.* Green lines at  $547\cdot 6$ ,  $530\cdot 2$

*Palladium.* Green lines at  $529\cdot 6$ ,  $511\cdot 7$ .







## WATER ANALYSIS.

S. E. MELLING, F.I.C.

For the complete diagnosis of the quality of water intended for domestic consumption, careful attention should be given to all available geological and meteorological data as well as to the chemical analysis, physical characteristics, microscopical features and bacteriological examination. In the absence of any geological and meteorological data, it may be impossible to account for the apparent anomalies which the various bio-chemical and other results indicate; hence the necessity for such local information as nature of strata and general catchment area, method of storage, proximity to human habitation, rainfall, etc.

### Sampling and delivery.

Correct sampling is of vital importance.

For chemical analysis, clean transparent 2½ litre bottles are convenient, the stoppers and necks being protected from dirt by some suitable form of capping. If drawn from tap or pump, the water should be allowed to run freely for several minutes (except, of course, in cases of plumbo-solvency determination) prior to the quiet filling of the bottle up to within, say, half an inch of the stopper. In sampling from a reservoir or stream, surface water should be excluded by holding the bottle one foot below the surface, and as far away from the bank as practicable, taking due precautions to avoid disturbing sediment. The interval between collection and examination is of great importance, and the shorter the interval, the more reliable will be the results, especially with reference to the organic data.

For bacteriological examination, the sampling must be carried out under strictly aseptic conditions, but it will rarely be necessary to collect more than about 200 cc. in a well-cleaned and previously sterilised stoppered bottle. If drawn from service mains, the water should be allowed to run for at least 15 minutes before sampling. In sampling from streams, it is of importance to remember that even flowing water deposits bacteria on the side of the stream bed; hence the sediment must on no account be disturbed. The most serviceable and simplest sampling apparatus is a modification of the Pasteur bulb in the form of a thick glass tube drawn out at one end to about 1/30 in. diameter. A small amount of pure water is introduced, boiled, and the tube sealed off whilst full of steam. When the tube is submerged, the drawn-out end is snapped with sterile forceps, and the broken end is then re-sealed. Suitable sterile metal containers are desirable for transport; it is preferable to



pack in an ice-box, but any device will serve which maintains the sample at or about  $4^{\circ}\text{C}$ . A simple apparatus such as the above may be used (duly weighted), with the aid of a fishing rod, for collecting samples from reservoirs, by attaching a stout thread to the sealed end of the tube and breaking at the right moment by a sharp pull.

### Physical Characteristics.

*Appearance.* Observation in a two-foot glass column is now replaced by more exact methods for turbidity determination (against pure silica suspensions, etc.), and for tintometric measurements, either by the Lovibond instrument or platinum-cobalt comparates. (For details of the latter see American Public Health Association, *Standard Methods of Water Analysis*, p. 9.)

*Odour.* An observation should be taken at the laboratory temperature after shaking the bottle vigorously when about two-thirds full. In addition about 200 cc. should be transferred to a clean capacious flask fitted with a pressure release, heated to about  $50^{\circ}\text{C}$ ., and the odour observed.

*Taste.* Occasionally, this observation is desirable, but useful information is only rarely gained.

### Chemical analysis.

The data required may include: total dissolved solids, suspended matter, nitrogen in organic and mineralised combinations, oxygen absorbed from acid permanganate, combined chlorine, hardness, and metallic contamination. Results should be expressed in parts per 100,000.

Before commencing the organic analysis, which must always take precedence over other analyses, a portion of the well-shaken sample should be transferred to a clean cylindrical separator, and set aside overnight to settle (see microscopical examination); the settled solution is drawn off for the combined chlorine and other estimations of inorganic matter in solution.

*Ammoniacal nitrogen* (free and saline ammonia). The still and condenser are freed from ammonia by distilling 400 to 500 cc. of pure water to about half its volume, and then collecting a further 50 cc., which should give a blank test on standing five minutes with Nessler solution; the remaining contents of the flask are rejected. 500 cc. of the freshly-shaken original sample are introduced into the flask together with 5 cc. of a 10% solution of ammonia-free sodium carbonate. (At either this stage or when the temperature is raised, a useful indication of the approximate amount of iron, lime and magnesia salts present is frequently afforded by the volume of precipitate; this may assist in determining the

amount of water to be subsequently taken for total saline matter and hardness estimations.) The distillation is carried out so that four 50 cc. quantities distil over in about 40 mins. Alternatively, 50 cc. is distilled off and Nesslerised; a further 150 cc. is collected in a cylinder, the ammonia content of which is determined by Nesslerising 50 cc. and calculating accordingly. Comparison is made with a series of suitable standards prepared by diluting standard ammonium chloride solution to 50 cc. in Nessler glasses with ammonia-free distilled water. (The latter is obtained, as required, by the distillation of tap-water to which has been added a slight excess of sulphuric acid.) Not more than 1 cc. of Nessler reagent<sup>2</sup> is necessary; the contents are mixed by pouring to and from a similar clean tube and are allowed to stand 5 mins. before comparison is made in specially clear tubes of identical internal diameter and make.

*Albuminoid nitrogen.* The contents of the distillation flask remaining after distillation of the ammoniacal nitrogen are allowed to cool somewhat, and 50 cc. of alkaline potassium permanganate<sup>3</sup> is added; four 50 cc. quantities are distilled off and ammonia estimated as above. A note is made of the rate of evolution of the ammonia.

*Organic nitrogen.* In routine sanitary analysis, this determination is rarely required. If essential, 500 cc. of the sample is evaporated to 100 cc., made alkaline with 10 cc. of 20 per cent. caustic soda solution, and a strip of aluminium foil introduced, when the reduction of nitrites and nitrates is completed in the course of 2 to 3 hrs.; the free ammonia is distilled off, and a Kjeldahl determination carried out on the residue.

*Nitrous nitrogen (nitrites).* Of the colorimetric methods available, probably that of Griess-Ilosvay is the most satisfactory. To 50 cc. of the sample (or, if necessary, 25 cc. made up to 50 cc. by the addition of nitrite-free distilled water) there is added 1 cc. each of sulphanilic acid<sup>4</sup> and  $\alpha$ -naphthylamine acetate;<sup>5</sup> after mixing thoroughly, the sample is compared with a range of suitable dilutions of standard sodium nitrite.<sup>6</sup> Ten minutes should be allowed for the full development of colour before final comparison.

*Nitric nitrogen (nitrates).* The phenoldisulphonic acid method, being specific, is recommended, but the procedure has to be varied according to the degree of turbidity, the presence of colour and the amount of combined chlorine. The two former factors can generally be ignored; in exceptional cases, clarification with pure alumina cream (freshly ppd. aluminium hydroxide washed free from alkali) will be found necessary. The presence of combined chlorine not exceeding 2 parts per

100,000 is without influence; otherwise it must be removed by first neutralising 50 cc. of the sample with pure N/50 sulphuric acid, followed by the addition of sufficient, but not excess of, pure silver sulphate solution; the liquid is then made up to 100 cc. with distilled water, shaken, and 50 cc. filtered for the estimation. The determination is made by carefully evaporating to dryness in a glass dish; towards the end of the evaporation, the mass is allowed to cool, and is spotted with 1 cc. of the phenoldisulphonic acid,<sup>7</sup> and thoroughly triturated with a glass rod. If the residue is at all vitreous, the dish is warmed on the water-bath for a brief period. The mass is treated with 25 cc. of distilled water, and the solution transferred to a 100 cc. graduated flask, rinsing with a small amount of water; excess of ammonia is added, and the liquid made up to the mark. The intensity of the yellow colour imparted by the ammonium compound is proportional to the amount present; comparison should be made in 50 cc. Nessler tubes with varying amounts of a standard solution containing potassium nitrate similarly treated,<sup>8</sup> diluted to the mark with distilled water after the addition of ammonia.

*Oxygen absorption test* (reducing power). 250 cc. of the sample in a stoppered bottle (less, if the water is seriously polluted) is acidified with 10 cc. of sulphuric acid,<sup>9</sup> 10 cc. N/80 solution of potassium permanganate<sup>10</sup> added, and the mixture allowed to stand for 3 hrs. at 18°C., giving the contents an occasional shake. A "control" test is made simultaneously under precisely the same conditions, using 250 cc. of recently-boiled and cooled distilled water. An excess 10% potassium iodide solution is now added to sample and control tests, and the liberated iodine determined by titration with sodium thiosulphate (1 grm. per litre), using starch solution as indicator. The amount of oxygen absorbed by the sample is calculated from the difference in the titrations.

A correction is necessary in case nitrites, ferrous iron, etc., are present.

*Total solids* (including suspended matter). A suitable quantity (100 cc. to 500 cc.) of the well-shaken sample is evaporated in a platinum dish on a water-bath. The residue is dried in the oven at 105°C. for an hour.

*Non-volatile solids.* The above residue is cautiously ignited, the temperature being gradually increased to a dull red heat. Observations on ignition frequently give valuable information; for example, degree of charring and odour (whether vegetable or nitrogenous organic matter), evolution of oxides of nitrogen, etc.

*Suspended matter.* In the majority of cases, water submitted for sanitary analysis contains only traces of suspended matter, and, unless a large volume of the sample is available, direct estimation is inexpedient. For this reason, it is doubtful whether much reliance can be placed upon the difference figure between the estimation of total solids of the shaken and filtered samples. Alternatively, in cases in which it is obvious that suspended matter is present in appreciable extent, say  $\frac{1}{2}$  grain per gallon or upwards, an estimation can be made of the deposit, after careful washing and centrifugalising, following its microscopical examination.

*Hardness.* The determination of the soap-destroying power of a water is generally affected by titration with standard soap solution, and is detailed in all books on water analysis. The process, whilst fairly reliable in the case of lime-hardness and for control work in water of known composition, is otherwise erratic and misleading. It is therefore preferable to proceed as outlined below ("Analysis of the mineral constituents of water").

*Combined chlorine.* A few drops of neutral potassium chromate solution are added to 50 cc. of the sample, which is then titrated with standard silver nitrate solution,<sup>11</sup> until a faint but permanent reddish tinge is attained. (In the presence of free acid or free alkali the water should first be suitably treated.)

*Metallic contamination* (with special reference to the presence of lead). 50 cc. of the clear sample is acidified with 3 drops of pure conc. acetic acid, and 2 cc. of freshly-prepared saturated solution of hydrogen sulphide added. In case sufficient lead is present to give a brown coloration, it is compared with the results obtained from varying amounts of a standard lead solution similarly treated. Before issuing a negative report, it is advisable whenever the volume of sample allows, to evaporate 250 cc. (or preferably 500 cc.) after acidifying with pure acetic acid, to 50 cc. and repeat the above test. Estimations of copper, tin, zinc, etc., require a larger amount of sample.

*Total acidity.* 50 to 100 cc. of the sample is titrated with N/50 sodium carbonate solution, using phenolphthalein as indicator, until the solution just turns pink. The result is expressed in terms of calcium carbonate. If the presence of free mineral acid is suspected, the test is repeated, using methyl orange as indicator.

*Analysis of the mineral constituents* of water follows along the usual lines, and will only be outlined for a restricted analysis, which may be suitably amplified in case a complete mineral analysis is desired. The alkalinity (which is temporary

hardness unless carbonate of soda is present) is determined by titrating a volume of the water, varying from 100 cc. to 500 cc. according to circumstances, with standard acid to exact neutrality, using methyl orange as indicator. The result is expressed in terms of  $\text{CaCO}_3$ . The total hardness is now ascertained by evaporating this neutral solution to low bulk in a platinum dish after the addition of a known excess of standard alkali, consisting of equimolecular proportions of  $\text{Na}_2\text{CO}_3$  and  $\text{NaOH}$ ; the residue is taken up with small quantities of hot distilled water, filtered and washed until all free alkali is removed. The excess of alkali in the filtrate is now determined, and the total hardness, in terms of  $\text{CaCO}_3$ , calculated accordingly. Now acidify slightly and estimate the sulphate. Alternatively, the total hardness is determined by dissolving the residue in standard acid and titrating the excess as usual. The titrated dissolved residue may be used for the estimation of iron, aluminium, calcium and magnesium. The sample is sometimes examined for phosphate, which, if present, might be of significance, but this is generally unnecessary.

### Microscopical examination of the deposit.

Occasionally enumeration of the various types of higher organisms present in a water is required; it is generally only necessary to classify plankton, of which the presence indicates sewage or allied organic contamination, or explains the origin of some specific complaint, such as odour or taste. The former involves a more elaborate technique, concentration of the particulate matter, micrometric counts in a large number of fields, etc. In routine examination the procedure is to tap off the deposit, accumulated overnight, from the separator (referred to under "Chemical Analysis") into one or more small centrifugal tubes, which are then whirled at a high speed. Several clean slides are prepared by taking up portions of the deposit with clean drawn-out tubing in the usual manner. The preparations are loosely covered and immediately examined, first with the lower and then with the higher powers.

(a) The only higher bacterial forms of significance are the filamentous (thread) organisms, some of which indicate a high degree of recent organic contamination. Typical examples are *Spharotilus natans*, *Cladothrix*, *Leptothrix* and *Crenothrix* forms, the two latter being more or less highly coloured, due to fixation of iron and/or manganese.

(b) The non-bacterial forms include diatomaceæ, chlorophyceæ, cyanophyceæ, the higher fungi, protozoa, crustacea, etc. The presence of many of these, for example, *Leptomitux*



(included in the higher fungi), ciliate infusoria, of which *Paramecium* and *Vorticella* may be taken as typical, flagellate organisms (*Euglena*, *Peridinium*, etc.), *Oscillatoria* and *Anabæna*, throw considerable light on the recent history of the water, and indicate potential, if not actual, danger. Whether the presence of one or other type can be definitely ascribed to sewage pollution is of secondary importance to the fact that they are usually associated with an unsatisfactory amount of fermentable organic matter. Certain of the more highly organised forms, for example, crustaceæ, function as purifying agents, and, whilst they may be harmless in themselves, often appreciably assist in the general diagnosis. To express a definite opinion that water has suffered pollution by sewage is not easy from the microscopical characteristic of the deposit, unless such pollution is gross, or the amount of sample available is very large. The presence of the ova or larvæ of human endoparasites, including *Tænia solium*, *Bothriocephalus*, *Trichocephalus dispar*, *Anchylostomum duodenale*, etc., is quite possible and must not be overlooked. As typical of the Vermes, *Anquillula* are not necessarily associated with sewage pollution, although frequently met with in waters of doubtful character. Again, the seasonal inoculation of supplies with such specific organisms as *Asterionella* (diatomaceæ), *Volvox*, *Pandorina*, *Anabæna*, etc. (algal type) and *Uroglæna*, *Peridinium*, etc., among the protozoa, frequently gives rise to objectionable tastes and odours. Others, for example, *Protococcus* and *Hæmatococcus plurialis*, may cause entire discoloration of storage supplies. Such conditions are usually overcome by the carefully-controlled introduction of algicidal agents of high potency (e.g., copper sulphate) without interfering, in any way, with the general quality of the water.

(c) Little significance is generally attached to the classification of amorphous matter, which includes mineral and organic debris, vegetable fibre and tissue, etc.

### Bacteriological examination.

Whilst the correct interpretation of the results of chemical analysis affords valuable information with respect to the character of the water and its past history, the data so far obtained is insufficient for the certification of any individual water as fit for use as a public supply. In order to be in a position to return the water as safe or otherwise for dietetic purposes, it is essential that it should be submitted to a more or less complete bacteriological examination. Such examination consists of: (a) the enumeration of the total number of organisms capable of growing on gelatin medium at 20°C., and on agar-agar medium at 37°C.; (b) the determination of

the presence or absence of the bacillus *Coli communis*, which, while not necessarily pathogenic in itself, is taken as indicative of the presence of organisms of intestinal origin; moreover, its identification is comparatively a simple matter. The usual procedure may be outlined as follows:—

*Total count.* Gelatin medium at 20°C. 10 cc. of the G.P.B. medium,<sup>12</sup> contained in a test-tube (6 in. by  $\frac{3}{4}$  in.) plugged with cotton-wool, is melted by placing the tube in water for a few minutes at a temperature of approximately 40°C., cooled to about 30°C., and a suitable volume of the water, diluted if necessary 1 : 10 or 1 : 100 with sterile distilled water, is added by means of a sterile graduated pipette. The cotton-wool plug is temporarily replaced, and the inoculated media thoroughly mixed by rolling the tube in a vertical position between the palms of the hands. The plug is then ignited and withdrawn by forceps, the tube being held in a slightly inclined position and the contents poured steadily into the lower plate of a sterile Petri dish of suitable size, holding the cover over the dish to avoid atmospheric contamination. The cover of the Petri dish is replaced, and the dish at once transferred to a levelled slab, at as low a temperature as possible to hasten solidification of the medium. The inoculated Petri dishes are incubated at 20°C. for 48 hrs. The number of colonies is counted on the plate, giving a reasonable field, and if desired, distinction is drawn between liquefying and non-liquefying colonies. In counting the colonies, Wolfhugel's or similar type of apparatus is used; the Petri dish is placed on the enumerating plate or disc, the cover removed and replaced by a plain, thin, sterilised piece of glass. A magnifying glass is used to pick out the colonies whenever necessary, and observations are made as to appearance, etc. The results are recorded in terms of "organisms per cc."

Agar-agar medium at 37°C.<sup>13</sup> The procedure adopted is similar to that described above, with the exception that, on account of the higher melting-point, the agar tubes are first immersed in water at approximately 60°C., and then cooled to about 43°C. before inoculation with the sample under examination. Means must also be adopted for avoiding the condensation of water on the upper plate of the Petri dish during incubation at the higher temperature; this may be overcome by employing a different type of Petri dish, in which the upper cover is made of porous material instead of glass, or the Petri dish may be inverted in the incubator and a special clip used which allows a space for the release of the moisture lost by evaporation. The organisms are usually enumerated after 48 hrs. incubation, and the results recorded in terms of "organisms per cc." as before.

### *Determination of the presence of B. Coli communis.*

*Presumptive tests.* Various preliminary methods for this purpose are employed, of which the two following examples may be given:—

(1) Inoculation of 0.1, 1.0, 10.0, and 100 cc. in varying strengths of lactose-litmus broth contained either in ordinary test-tubes in which are placed small Durham fermentation tubes for the collection of any gas evolved, or in V-shaped tubes sealed at one end, in which the gas evolved is measured in the upper closed limb of the tube. The inoculated tubes are incubated at 37°C., and examined for acidity and gas production at the end of 24 and 48 hrs. incubation. The general practice is to return the results as positive presumptive evidence where both acid and gas are manifest after 24 hrs. incubation. If gas is not evolved until 48 hrs. have elapsed, the results are treated as doubtful, and should be subject to confirmatory tests yielding positive results.

(2) Inoculation of corresponding volumes of the water in tubes with internal Durham tubes, containing either single, double or triple strength McConkey solution,<sup>14</sup> depending on the volume of water tested. This is the method adopted by Houston for the determination of presumptive *B. Coli*. The presence of acid or gas is noted at the end of 24 and 48 hrs. incubation.

If these presumptive tests yield negative results with volumes of the water exceeding 10 cc., it is not usual to proceed further, but if positive results are obtained with 10 cc. or less of the water, such results should be corroborated by the application of confirmatory tests. In general practice it has been found that 90% of positive presumptive tests are confirmed as typical *B. Coli*, and consequently many observers rely entirely on the presumptive test. The various confirmatory methods employed include a series of fermentation tests on various sultanas, *e.g.*, mannitol, dulcitol, etc. One of the simplest confirmatory tests is to take the litmus-broth tube or the McConkey solution tube which gives positive results with the least volume of water, and re-inoculate into litmus-lactose agar,<sup>15</sup> plate and re-incubate. Any typical acid organisms may then be examined microscopically, picked out and re-inoculated into the original tubes used for the presumptive test, and the result noted after 24 hrs. further incubation. The final results may be recorded as, for example, "absent in 1 cc., present in 10 cc."; "absent in 0.1 cc., present in 1 cc.," etc.

### **Standard solutions.**

(1) Standard ammonium chloride solution, 3.82 grm. of



ammonium chloride is dissolved in 1000 cc. of ammonia-free distilled water.

1 cc. = 0.001 grm. N. (stock solution).

10 cc. of the above solution is diluted to a litre with ammonia-free distilled water.

1 cc. = 0.01 mgrm. N.

(2) Nessler's solution. 13 grm. of mercuric chloride dissolved in 500 cc. of distilled water is mixed with 35 grm. of potassium iodide in 100 cc. of distilled water, and saturated mercuric chloride solution is added until a slight permanent precipitate of mercuric iodide is obtained. 120 grm. of sodium hydroxide dissolved in 200 cc. of water is added cold, and the solution made up to 1 litre with distilled water.

(3) Alkaline potassium permanganate. 200 grm. of potassium hydroxide dissolved in 500 cc. of water is mixed with a solution of 8 grm. of potassium permanganate in 750 cc. of water, and the solution evaporated to 1000 cc.

(4) Sulphanilic acid. 1 grm. is heated on a water-bath with 15 cc. of glacial acetic acid and 50 cc. of distilled water, and the solution is diluted to 285 cc. with distilled water.

(5)  $\alpha$ -Naphthylamine acetate. 0.2 grm. is treated as under sulphanilic acid, diluting the solution to 325 cc.

(6) Standard sodium nitrite solution. 0.25 grm. of pure anhydrous sodium nitrite is dissolved in 500 cc. of distilled water, and the strength determined by titration with N/80 potassium permanganate solution. From this stock solution the working solution is prepared so that:

1 cc. = 0.001 mgrm. N.

The stock solution is preserved in a dark-coloured bottle.

(7) Phenol disulphonic acid. 15 grm. of pure phenol is heated for 6 hrs. on a water-bath with 100 cc. of pure concentrated sulphuric acid.

(8) Standard nitrate solution. 0.722 grm. of pure potassium nitrate is dissolved in 1000 cc. of distilled water. 100 cc. of this solution, evaporated just to dryness in a small porcelain dish, is treated with 2 cc. of the phenol disulphonic acid, mixing thoroughly with a glass rod, and the solution is diluted to 1000 cc. with distilled water.

1 cc. = 0.01 mgrm. N.

(9) Dilute sulphuric acid for oxygen absorption test. One volume of pure sulphuric acid is diluted with three volumes of distilled water, and a very small amount of potassium permanganate solution added cautiously until faintly pink.

(10) Standard solution of potassium permanganate for oxygen absorption test. 0.395 grm. of pure potassium permanganate is dissolved in 1000 cc. of distilled water.

1 cc. = 0.1 mgrm. available oxygen.

(11) Standard solution of silver nitrate. 4.791 grm. of pure silver nitrate is dissolved in 1000 cc. of distilled water.

1 cc.  $\equiv$  0.001 grm. Cl.

(12) Gelatin medium (G.P.B.). A litre of broth is prepared by gently boiling 1 lb. of lean beef, chopped into small pieces, with a litre of water for 3 hrs. When cool, the fat is removed, and the mixture filtered and made up to a litre. 10 grm. of peptone, 5 grm. of salt, and, gradually, 120 grm. of gelatin are added to the boiling solution until dissolved, when it is made alkaline by addition of 11 cc. of 20% sodium hydroxide solution. White-of-egg is added to the lukewarm solution, which is then sterilised for 45 mins. by steaming, and allowed to stand for 15 mins. before filtering into tubes (about 12 cc. per tube). The tubes are re-sterilised for 45 mins. on two consecutive days.

(13) Agar-agar medium (A.P.B.). 20 grm. of agar (fibre) is cleaned by treatment with 500 cc. of water and 2.5 cc. of glacial acetic acid for 1 hr., and then washed thoroughly until acid-free. A litre of broth is boiled with peptone and salt as under (12), the agar introduced, and the mixture autoclaved for 30 mins. The lukewarm solution is made alkaline with 6 cc. of 20% sodium hydroxide solution, clarified as under (12), autoclaved for 45 mins., filtered through a hot-water filter, and tubed for slopes and plates. The tubes are re-sterilised for 45 mins. on two successive days.

(14) McConkey medium. The quantities of ingredients used in the preparation of the various strengths of this medium are as follows:—

|                              | Single<br>strength. | Double<br>strength. | Triple<br>strength. |
|------------------------------|---------------------|---------------------|---------------------|
| Peptone, grm. . . . .        | 20                  | 40                  | 100                 |
| Lactose, grm. . . . .        | 10                  | 20                  | 50                  |
| Bile salt, grm. . . . .      | 5                   | 10                  | 25                  |
| Litmus, 1%, cc. . . . .      | 100                 | 200                 | 500                 |
| Water, cc. . . . .           | 900                 | 800                 | 500                 |
| NaOH soln., 20%, cc. . . . . | 1.25                | 2.0                 | 3.0                 |

The 1% litmus solution is prepared by digesting 2 oz. of powdered litmus with successive quantities of hot water, decanting the solution; the extract is evaporated, and any carbonate present decomposed with a slight excess of acetic acid; the evaporation is continued until the mass is pasty, and the azolitmin precipitated with 200 cc. of 90% alcohol; the precipitate is filtered off, washed well with alcohol, dissolved in warm distilled water, and made up to 500 cc. Solution is effected by heating the solid constituents with the water, filtering, and then adding the alkali and litmus solution. The medium is distributed into Durham fermenta-

tion tubes, and sterilised on three successive days by 30 mins. steaming. In the test 10 cc. of the single-strength medium is used for 1 cc. of the sample; 10 cc. of the double-strength medium for 10 cc. of the sample; and 25 cc. of the triple-strength medium for 100 cc. of the sample.

(15) *Litmus-lactose-agar medium*. This medium is prepared as under nutrient agar (13), with the exception that 1% of lactose is added prior to sterilisation, and the medium neutralised, using phenol-phthalein as indicator. 1 cc. of sterilised litmus solution is placed in the Petri dish when plating.

#### *Interpretation of Results.*

Owing to the extreme difficulty of distinguishing between nitrogen of vegetable origin and that due to sewage or allied contamination, great care must be exercised in the interpretation of the results of the chemical analysis of water, and particularly so in the absence of information relating to the source of the water. For this reason very little value is to be attached to tables purporting to lay down so-called limits of impurity, as measured by the amount of oxidisable matter determined by the oxygen absorbed from acid permanganate of potash, and/or the amount of albuminous matter gauged from the albuminoid ammonia determination. Information obtained from the results of chemical examination of a large number of waters from widely different gathering grounds, shows that, in certain instances, waters which are of a high degree of organic purity may not be bacteriologically sound and *vice versa*. Waters free from sewage or similar impurity may yield relatively high figures for oxidisable matter and albuminoid ammonia derived from purely vegetable sources.

It follows that, before the analyst expresses a definite opinion upon a sample of water (unless he is in possession of special knowledge as to its history from source to consumer), the chemical results should be correlated with those obtained from a bacteriological examination. In considering the data given by the latter, the total count of the organisms do not necessarily indicate the origin of the water, and greater significance must be attached to the type of organism present. On the other hand, a high count of organisms developing at blood-heat must be looked upon with suspicion. It is desirable that, in the case of a public water supply, the total number of organisms growing in agar-agar medium should not exceed 10 per cc. The same limit should be observed in deep wells, whilst, if the water is of surface origin, a maximum of 100 per cc. should not be exceeded. So far as the *B. Coli* organism is concerned, in the case of deep well water it should not be present in quantities less than 100 cc., and, for surface

or shallow well supplies, a reasonably safe standard requires that it should be absent in quantities of 10 cc. or less.

### Sewage and Effluent Analysis.

The routine examination of sewage includes much of the data already outlined in the previous section, *e.g.*, estimation of free and saline ammonia, albuminoid ammonia, nitrogen in mineralised form, oxygen absorbed from acid permanganate in 4 hrs., combined chlorine, etc. It is therefore only necessary to modify slightly the methods in respect of the amounts of the sample taken for the several determinations. If, as a routine measure, it is desired to test the efficiency of a sewage treatment, it is usual to base the percentage of purification obtained upon either the respective yields of albuminoid ammonia from untreated sewage and effluent, or the reduction in oxidisable matter indicated by the permanganate test.

With respect to the requirements of the Rivers Pollution Prevention Act, however, the two deciding factors of the quality of a sewage effluent—other than the possible presence of toxic bodies, etc.—are (1) the amount of suspended solids present, and (2) the amount of dissolved oxygen which the sample is capable of abstracting from tap-water (after suitable dilution) on incubation for five days at 18°C. After careful deliberation, the Royal Commissioners, in their eighth report on Sewage Disposal, recommended that the former should not exceed three parts, and the latter two parts, per 100,000 of the effluent. The methods of determination are detailed in that Report, Part 2, Sections 2 and 3. The tests recommended were briefly :

*Suspended solids.* A suitable quantity of the effluent is filtered through a Gooch crucible fitted with an asbestos mat (which must take up some of the colloids present). Non-volatile solids are determined by ignition in the usual manner.

*Dissolved Oxygen.* The shaken sample is mixed quietly with 4 vols. of aerated tap-water. One portion is transferred to stoppered bottle, which is *completely* filled and is placed in an incubator at 18°C. for 5 days, at the end of which period the dissolved oxygen remaining is determined. The dissolved oxygen content of the remaining portion of the sample is immediately ascertained by the Winkler method (Rideal-Stewart modification), which depends upon the oxidation of manganese hydroxide to manganous acid and the iodimetric determination of the amount of oxygen taken up by the addition of hydrochloric acid and potassium iodide to the solution; the liberated iodine is titrated with standard sodium thiosulphate. The difference between the initial and final

oxygen contents, multiplied by 5, gives the amount of dissolved oxygen taken up in this period.

In general practice the procedure laid down in that Report may with advantage be simplified. For example, centrifugal methods may be employed for the estimation of particulate suspended matter, thus avoiding the inclusion of colloids, part of which may be included in filtration processes. Further, in the absence of nitrites or other active reducing bodies, preliminary acidification and oxidation, with subsequent removal of excess potassium permanganate, may be omitted, whilst it is permissible, when the hydrochloric acid has completely dissolved the manganese hydroxides, to transfer the whole of the contents of the bottle to a capacious flask for titration with the thiosulphate.

Whilst strictly legal standards are non-existent, it will be obvious from the above remarks that the necessary requirements are as follows: An effluent must contain neither mineral acid, caustic alkali, antiseptic nor poisonous substance; it must be reasonably free from suspended matter; and it must be sufficiently stable, in a bio-chemical sense, as not to affect prejudicially the character of the stream into which it is discharged.

The waste waters from manufacturing premises vary so profoundly in character that, beyond some elasticity in the permissible amount of suspended solids (as compared with sewage effluents), it is more necessary to stress the importance of taking local circumstances into full consideration, and treating each case on its merits, than to attempt to define limits of composition.

---

### Bibliography.

- Metropolitan Water Board Reports. A. C. Houston.
- Studies in Water Supply. A. C. Houston.
- Examination of Waters and Water Supplies. J. C. Thresh.
- The Microscopy of Drinking Water. G. C. Whipple.
- The Bacteriological Examination of Water Supplies. W. G. Savage.
- Sewage Works Analyses. G. J. Fowler.
- Standard Methods for the Examination of Water and Sewage. American Public Health Association.
- Recommended Methods for Physical and Chemical Examination of Water and Sewage. Provincial Board of Health of Ontario.
- Eighth Report of the Royal Commission on Sewage Disposal. Pt. 2. Sections 2 and 3.



# FUELS AND ILLUMINANTS.

H. MOORE, M.Sc. Tech.

*Absolute Heating Effect or Calorific Power.*

The approximate calorific power may be calculated from the ultimate analysis by means of the formula :

$$W = \frac{34500 (H - \frac{1}{8} O) + 8137 C}{100}$$

or, taking into account the latent heat of vaporisation required for the hygroscopic water :

$$W = \frac{34500 (H - \frac{1}{8} O) + 8137 C - 600 H_2O}{100}$$

The figure 34500 calories, used in this formula, is obtained with hydrogen when the products of combustion contain the water in the liquid state. In practice, the water formed by combustion leaves the combustion zone in the state of steam.

Working on the latter assumption, a lower calorific value is obtained. When allowance has been made for the latent heat of vaporisation and the specific heat it is found that one gram of steam carries away approximately 600 cal. of heat. As one gram of hydrogen forms nine grains of water, the loss per gram hydrogen will be 5,400 cal.; therefore  $34500 - 5400 = 29100$  calories will be available. If the sulphur content of a fuel be known, the calorific power of its combustion to  $SO_2$  should be taken into account (2200 cal. per gram); as, however, a portion is burnt to  $SO_3$  (3300 cal.) it is preferable to consider the value as 2500 cal.

The formula then becomes

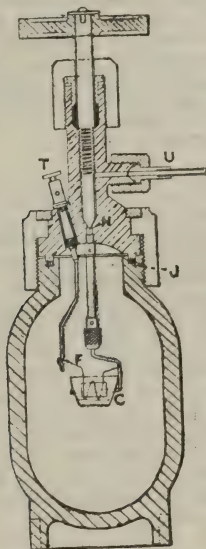
$$W = \frac{8137 C + 29100 (H - \frac{1}{8} O) + 2500 S - 600 H_2O}{100}$$

This formula is only approximate, as the carbon and hydrogen are not present as elements but in combination; moreover, the the oxygen is not present in the form of water.

W/636 is the theoretical evaporating power, that is the weight of water at  $0^\circ C$ . which a given weight of fuel will convert into steam at  $100^\circ C$ ., assuming that the carbon and hydrogen are burnt to  $CO_2$  and  $H_2O$ .

The most reliable and accurate method of determining the calorific value is by burning the substance and measuring the heat evolved in a calorimeter. The best instrument for

this purpose is the bomb calorimeter originally devised by Berthelot. Many forms of this instrument are at present available; they are all similar in the more important features. The bomb calorimeter consists of a strong steel chamber, the inside of which is coated with platinum or enamel. This vessel must be capable of standing a pressure of at least 50 atmospheres (750 lbs. per square inch) and forms the chamber in which the combustion takes place. The bomb is filled with oxygen at a pressure of approximately 20 atmospheres (300 lbs. per square inch), the ignition of the fuel being obtained by fusing a thin platinum or iron wire by means of an electric current.



Section of Mahler-Cook Bomb.

T = Insulated Terminal.  
J = Lead Joint.  
F = Fuse Wire.

N = Needle Valve.  
C = Crucible.  
U = Union to Oxygen Supply.

The bomb is immersed in water contained in a vessel, the whole being then placed in a case provided with special devices to obtain the thermal insulation of the vessel. The container is provided with a stirring arrangement and a special Beckman thermometer (graduated to  $\frac{1}{100}^{\circ}\text{C}$ ). By taking readings of the thermometer before and after combustion the rise in temperature of the bomb, water and container is found. As the bomb and container are never perfectly insulated from their surroundings an interchange of heat from one to the other takes place during the experiment. This heat is mainly transferred by radiation, and in order to obtain accurate results it is necessary to make a correction for this when calculating the calorific power of a fuel from the results of an experiment. In order to simplify the calculation and to ensure accuracy, it is most satisfactory to wait until the temperature of the container becomes constant before firing the charge. Readings are taken at regular intervals until the temperature of the container is falling at a uniform rate. A satisfactory method of calculating the radiation correction is by means of the following formula:

$$\text{Correction} = K (t_2 - t_1 + t_3 - t_2 + t_4 - t_3 \dots + t_n - t_{n-1});$$

where  $t_1, t_2, t_3$ , etc., are the initial, second, third, etc., temperature readings,  
 $t_n$  is the maximum temperature reading,  
 $K$  is the decrease in temperature per interval after maximum temperature.

It is also necessary to make a correction for sulphur if it be present in the fuel. The sulphur dioxide found in a bomb calorimeter reacts with oxygen and water, thus generating more heat than under normal conditions of combustion. The correction to be subtracted from the calculated calorific power is 22.5 calories for each 1% of sulphur present in the fuel.

A further deduction must be made of 227 calories for each gram of nitric acid present in the bomb at the end of the experiment. Referring to tests of coal, Brame states that the nitric acid correction is usually of the order of 15 calories, and the sulphur 20 calories.

In determining the calorific value of gases special calorimeters are employed. A suitable example of this type of instrument is the Junker calorimeter. This consists of a chamber through which a measured quantity of water flows; the chamber is heated by a Bunsen burner consuming the gas at a measured rate. The chamber is so arranged that a very high thermal efficiency is obtained, that is to say, the heat of the flame is almost completely transferred to the water. If  $G$



be the quantity of gas burnt (in litres), W the weight of water in grams leaving the calorimeter, T the temperature difference between inlet and outlet water, the calorific value of the gas is:

$$H = \frac{W.T}{G} \text{ calories.}$$

If the products of combustion contain the water in the form of steam, then

$$H = \frac{W.T - 600 H_2O}{G} \text{ calories.}$$

If the pressure (h) and the temperature (t) of the gas are taken into consideration, in order to obtain the results in terms of 15°C. and 760 mm. the following formula is employed :

$$H = \frac{W.T - 600 H_2O}{G} \times \frac{273 + t}{288} \times \frac{760}{h}$$

In Britain it is usual to state results in B.Th.U. per cubic ft. The results are determined in calories per cubic ft., and the calories then calculated to B.Th.U. by multiplying by 3.968.

### *Calorific Intensity.*

The calorific intensity may be determined by a pyrometer, or calculated from the calorific value and the specific heats of the products. The former is the more satisfactory method, but the results obtained vary considerably according to the conditions under which combustion takes place. The specific heats of the products of combustion are not known to any close degree of accuracy. The theoretical temperatures obtained by calculation are also affected by loss of heat due to conduction and radiation, and by dissociation of the products of combustion at high temperatures.

### *Air Required for Combustion. (A.)*

The theoretical weight of air required to burn one kilogram of fuel consisting of C, H and O can be obtained from the following equation :

$$A = 0.0116 [C + 3 (H - \frac{1}{8} O)] \text{ Kg.}$$

where C, H, and O are grams of carbon, hydrogen, and oxygen per kilogram of fuel.

For heating with coal with a natural draught, the amount of air required may be taken as 2A, with wood or with forced draught  $1\frac{1}{2}A$ . For gas firing the figure 1A may be closely approximated.

# Calorific Properties of Various Solid Fuels.

| Substance.                                   | Calorific Power. |           | Observed by            |
|--|------------------|-----------|------------------------|
|  | calories.        | B. Th. U. |                        |
| Scotch peat briquettes (16% $H_2O$ )         | 4,754            | 8,558     | F. Mollwo Perkin.      |
| Coke from Scotch peat .. .. .                | 7,600            | 13,680    | " "                    |
| Oak (containing 13.3 % $H_2O$ ) ..           | 3,990            | 7,182     | Gottlieb.              |
| " " 11.8 " ..                                | 4,155            | 7,479     | " "                    |
| Yoke elm " 12.2 " ..                         | 4,151            | 7,490     | " "                    |
| Beech " 12.95 " ..                           | 4,168            | 7,502     | " "                    |
| " " 13.95 " ..                               | 4,101            | 7,382     | " "                    |
| " " 13.75 " ..                               | 4,114            | 7,405     | " "                    |
| Birch " 11.83 " ..                           | 4,207            | 7,573     | " "                    |
| Pine " 12.17 " ..                            | 4,422            | 7,960     | " "                    |
| Fir " 11.80 " ..                             | 4,485            | 8,073     | " "                    |
| Anthracite .. .. .                           | 8,400            | 15,120    | Dosch.                 |
| Anthracite from Westphalia ..                | 7,575            | 13,635    | Langbein.              |
| Short flame sinter coal .. ..                | 8,200            | 14,760    | Dosch.                 |
| Kentucky coal (U.S.A.) .. ..                 | 7,785            | 14,013    | U.S. Geological Survey |
| Illinois coal (U.S.A.) .. ..                 | 7,056            | 12,701    | " "                    |
| Pennsylvania coal (U.S.A.) ..                | 7,875            | 14,175    | " "                    |
| Coke .. .. .                                 | 6,900            | 12,420    | Dosch.                 |
| Coke .. .. .                                 | 6,919            | 12,454    | Langbein.              |
| Lignite .. .. .                              | 4,000            | 7,200     | Dosch.                 |
| Earthy lignite .. .. .                       | 3,000            | 5,400     | " "                    |
| Lignite briquettes .. .. .                   | 4,668            | 8,402     | Langbein.              |
| Lignite from Saxony (moist) ..               | 2,622            | 4,720     | " "                    |
| Peat .. .. .                                 | 4,230            | 7,614     | " "                    |
| Sawdust briquettes .. .. .                   | 4,065            | 7,317     | " "                    |
| Asphaltum (extracted from petroleum) .. .. . | 9,550            | 17,190    | H. Moore.              |
| Dry peat (average from bog) ..               | 4,490            | 8,100     | Anderson and Dillner.  |
| " " .. .. .                                  | -6,140           | -11,000   | " "                    |
| Dry reed grass peat .. .. .                  | 4,140            | 7,450     | " "                    |
| " " .. .. .                                  | -5,460           | -9,820    | " "                    |
| Dry mud peat .. .. .                         | 4,360            | 7,825     | " "                    |
| " " .. .. .                                  | -4,560           | -8,200    | " "                    |

# OXYGEN AND AIR REQUIRED TO BURN "N" PARTS OF VARIOUS FUELS.

| N =  |          | 1       | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      |
|--|----------|---------|--------|--------|--------|--------|--------|--------|--------|--------|
| N Kg C<br>require                              | Kg.O.    | 2.6667  | 5.3333 | 8.0000 | 10.667 | 13.333 | 16.000 | 18.667 | 21.333 | 24.000 |
|  | Kg.Air   | 11.5011 | 23.002 | 34.503 | 46.004 | 57.505 | 69.006 | 80.508 | 92.009 | 103.51 |
|  | Cb.m.O.  | 1.8643  | 3.7286 | 5.5928 | 7.4571 | 9.3214 | 11.186 | 13.050 | 14.914 | 16.778 |
|  | Cb.m.Air | 8.8944  | 17.789 | 26.683 | 35.578 | 44.472 | 53.367 | 62.261 | 71.156 | 80.050 |
| N Kg H<br>require                              | Kg.O.    | 7.98    | 15.96  | 23.94  | 25.92  | 39.90  | 47.88  | 55.86  | 63.84  | 71.82  |
|  | Kg.Air   | 34.4170 | 68.834 | 103.25 | 137.67 | 172.08 | 206.50 | 240.92 | 275.34 | 309.75 |
|  | Cb.m.O.  | 5.5788  | 11.158 | 16.737 | 23.315 | 27.894 | 33.473 | 39.032 | 44.631 | 50.210 |
|  | Cb.m.Air | 26.5984 | 53.197 | 79.795 | 106.39 | 132.99 | 159.59 | 186.19 | 212.79 | 239.39 |
| N Kg CO<br>require                             | Kg.O.    | 0.5714  | 1.1429 | 1.7143 | 2.2857 | 2.8571 | 3.4286 | 4.0000 | 4.5714 | 5.1429 |
|  | Kg.Air   | 2.4645  | 4.9291 | 7.3936 | 9.8582 | 12.323 | 14.787 | 17.252 | 19.716 | 22.181 |
|  | Cb.m.O.  | 0.3995  | 0.7990 | 1.1985 | 1.5979 | 1.9974 | 2.3969 | 2.7964 | 3.1959 | 3.5954 |
|  | Cb.m.Air | 1.9046  | 3.8093 | 5.7139 | 7.6186 | 9.5232 | 11.428 | 13.333 | 15.237 | 17.142 |
| N Kg CH <sub>4</sub><br>require                | Kg.O.    | 3.9975  | 7.9950 | 11.992 | 15.900 | 19.987 | 23.985 | 27.982 | 31.980 | 35.978 |
|  | Kg.Air   | 17.2410 | 34.482 | 51.723 | 68.964 | 86.205 | 103.45 | 120.69 | 137.93 | 155.17 |
|  | Cb.m.O.  | 2.7947  | 5.5893 | 8.3840 | 11.179 | 13.973 | 16.769 | 19.563 | 22.357 | 25.152 |
|  | Cb.m.Air | 13.3291 | 26.658 | 39.987 | 53.317 | 66.646 | 79.975 | 92.304 | 106.63 | 119.96 |
| N Kg C <sub>2</sub> H <sub>4</sub><br>require  | Kg.O.    | 3.4273  | 6.8547 | 10.282 | 13.719 | 17.137 | 20.564 | 23.991 | 27.419 | 30.846 |
|  | Kg.Air   | 14.7820 | 29.564 | 44.346 | 59.128 | 73.910 | 89.692 | 103.47 | 118.26 | 133.04 |
|  | Cb.m.O.  | 2.3961  | 4.7921 | 7.1882 | 9.5843 | 11.980 | 14.376 | 16.772 | 19.169 | 21.565 |
|  | Cb.m.Air | 11.4280 | 22.856 | 34.284 | 45.712 | 57.140 | 68.568 | 79.996 | 91.424 | 102.86 |
| N Cbm H<br>require                             | Kg.O.    | 0.7174  | 1.4348 | 2.1522 | 2.8696 | 3.5870 | 4.3044 | 5.0218 | 5.7392 | 6.4566 |
|  | Kg.Air   | 3.0941  | 7.1881 | 9.2822 | 12.376 | 15.470 | 18.564 | 21.658 | 24.752 | 27.847 |
|  | Cb.m.O.  | 0.5015  | 1.0031 | 1.5046 | 2.0061 | 2.5077 | 3.0092 | 3.5107 | 4.0123 | 4.5138 |
|  | Cb.m.Air | 2.3912  | 4.7823 | 7.1735 | 9.5647 | 11.956 | 14.347 | 16.738 | 19.129 | 21.521 |
| N Cbm CO<br>require                            | Kg.O.    | 0.7174  | 1.4349 | 2.1523 | 2.8697 | 3.5872 | 4.3046 | 5.0220 | 5.7394 | 6.4569 |
|  | Kg.Air   | 3.0942  | 6.1885 | 9.2827 | 12.377 | 15.471 | 18.565 | 21.660 | 24.754 | 27.848 |
|  | Cb.m.O.  | 0.5016  | 1.0031 | 1.5047 | 2.0062 | 2.5078 | 3.0094 | 3.5109 | 4.0125 | 4.5140 |
|  | Cb.m.Air | 2.3913  | 4.7826 | 7.1739 | 9.5652 | 11.957 | 14.348 | 16.739 | 19.130 | 21.522 |
| N Cbm CH <sub>4</sub><br>require               | Kg.O.    | 2.8696  | 5.7391 | 8.6087 | 11.478 | 14.348 | 17.217 | 20.087 | 22.957 | 25.826 |
|  | Kg.Air   | 12.3763 | 24.753 | 37.129 | 49.505 | 61.882 | 74.258 | 86.634 | 99.010 | 111.39 |
|  | Cb.m.O.  | 2.0061  | 4.0123 | 6.0184 | 8.0245 | 10.031 | 12.037 | 14.043 | 16.049 | 18.055 |
|  | Cb.m.Air | 9.5682  | 19.136 | 28.705 | 38.273 | 47.841 | 57.409 | 66.978 | 76.546 | 86.114 |
| N Cbm C <sub>2</sub> H <sub>4</sub><br>require | Kg.O.    | 4.3044  | 8.6087 | 12.913 | 17.217 | 21.522 | 25.826 | 30.131 | 34.435 | 38.739 |
|  | Kg.Air   | 18.5645 | 37.129 | 55.693 | 74.258 | 92.822 | 111.39 | 129.95 | 148.52 | 167.08 |
|  | Cb.m.O.  | 3.0092  | 6.0184 | 9.0276 | 12.037 | 15.046 | 18.055 | 21.064 | 24.074 | 27.083 |
|  | Cb.m.Air | 14.3524 | 28.705 | 43.057 | 57.409 | 71.762 | 86.114 | 100.47 | 114.82 | 128.27 |

## HEAT OF COMBUSTION WITH OXYGEN OR AIR

The following determinations were made by Berthelot (B)  
Favre and Silbermann (F), Thomsen (Th) and Stohman (St).

| Substance.   | Products of Combustion.                   | Calories        | Calories         | Observed by |
|--|---|-----------------|------------------|-------------|
|  |   | K per Kilogram. | K per Gram. Mol. |             |
| Wood charcoal  | CO <sub>2</sub>                           | 8080            | 96.96            | F           |
| Wood charcoal  | CO <sub>2</sub>                           | 8137            | 97.65            | B           |
| Sugar charcoal   | CO <sub>2</sub>                           | 8040            | —                | F           |
| Retort graphite  | CO <sub>2</sub>                           | 8047            | 96.57            | F           |
| Blast furnace graphite                                   | CO <sub>2</sub>                           | 7762            | —                | F           |
| Blast furnace graphite                                   | CO <sub>2</sub>                           | 7901            | 94.81            | B           |
| Natural graphite   | CO <sub>2</sub>                           | 7997            | —                | F           |
| Carbon monoxide  | CO <sub>2</sub>                           | 2403            | 67.28            | F           |
| Carbon monoxide  | CO <sub>2</sub>                           | 2440            | 68.34            | B           |
| Wood charcoal  | CO  | 2473            | 29.7             | F           |
| Wood charcoal  | CO  | 2442            | 29.3             | B           |
| Hydrogen   | H <sub>2</sub> O liquid                   | 34462           | 68.9             | F           |
| Hydrogen   | H <sub>2</sub> O liquid                   | 34180           | 68.36            | Th          |
| Hydrogen   | H <sub>2</sub> O steam                    | 28800           | 57.4*            | Th          |
| Hydrogen   | H <sub>2</sub> O steam                    | 29150           | 58.3*            | B           |
| Methane CH <sub>4</sub>                                  | CO <sub>2</sub> + H <sub>2</sub> O liquid | 13063           | 209.0            | F           |
| Methane CH <sub>4</sub>                                  | CO <sub>2</sub> + H <sub>2</sub> O liquid | 13344           | 213.5            | B           |
| Methane CH <sub>4</sub>                                  | CO <sub>2</sub> + H <sub>2</sub> O steam  | 12066           | 191.7            | B           |
| Acetylene C <sub>2</sub> H <sub>2</sub>                  | CO <sub>2</sub> + H <sub>2</sub> O liquid | 11927           | 318.1            | B           |
| Acetylene C <sub>2</sub> H <sub>2</sub>                  | CO <sub>2</sub> + H <sub>2</sub> O steam  | 11527           | 299.7            | Th          |
| Ethylene C <sub>2</sub> H <sub>4</sub>                   | CO <sub>2</sub> + H <sub>2</sub> O liquid | 11858           | 332.0            | F           |
| Ethylene C <sub>2</sub> H <sub>4</sub>                   | CO <sub>2</sub> + H <sub>2</sub> O liquid | 12072           | 341.4            | B           |
| Ethylene C <sub>2</sub> H <sub>4</sub>                   | CO <sub>2</sub> + H <sub>2</sub> O steam  | 11293           | 316.2            | B           |
| Propylene C <sub>3</sub> H <sub>6</sub>                  | CO <sub>2</sub> + H <sub>2</sub> O liquid | 11934           | 507.3            | B           |
| Propylene C <sub>3</sub> H <sub>6</sub>                  | CO <sub>2</sub> + H <sub>2</sub> O steam  | 11155           | 468.5            | B           |
| Benzene C <sub>6</sub> H <sub>6</sub> (gaseous)          | CO <sub>2</sub> + H <sub>2</sub> O liquid | 10070           | 783.2            | B           |
| Benzene C <sub>6</sub> H <sub>6</sub> (gaseous)          | CO <sub>2</sub> + H <sub>2</sub> O steam  | 9650            | 752.6            | calc.       |
| Benzene C <sub>6</sub> H <sub>6</sub> (liquid)           | CO <sub>2</sub> + H <sub>2</sub> O liquid | —               | 779.8            | St          |
| Naphthalene C <sub>10</sub> H <sub>8</sub>               | CO <sub>2</sub> + H <sub>2</sub> O liquid | 9664            | 1243.0           | B           |
| Naphthalene C <sub>10</sub> H <sub>8</sub>               | CO <sub>2</sub> + H <sub>2</sub> O steam  | 9328            | 1194.0           | calc.       |
| Paraffin   | CO <sub>2</sub> + H <sub>2</sub> O liquid | 11140           | —                | St          |
| Paraffin   | CO <sub>2</sub> + H <sub>2</sub> O steam  | 10340           | —                | St          |
| Hexane C <sub>6</sub> H <sub>14</sub>                    | CO <sub>2</sub> + H <sub>2</sub> O liquid | 11525           | 991.2            | St          |
| Hexane C <sub>6</sub> H <sub>14</sub>                    | CO <sub>2</sub> + H <sub>2</sub> O steam  | 10636           | 914.8            | St          |
| Heptane C <sub>7</sub> H <sub>16</sub>                   | CO <sub>2</sub> + H <sub>2</sub> O liquid | 11375           | 1137.5           | L           |
| Alcohol C <sub>2</sub> H <sub>5</sub> O                  | CO <sub>2</sub> + H <sub>2</sub> O liquid | 7184            | 330.5            | F           |
| Alcohol C <sub>2</sub> H <sub>5</sub> O                  | CO <sub>2</sub> + H <sub>2</sub> O liquid | 7054            | 324.5            | B           |
| Glycerin C <sub>3</sub> H <sub>8</sub> O <sub>3</sub>    | CO <sub>2</sub> + H <sub>2</sub> O liquid | 4316            | 397.1            | St          |
| Starch C <sub>6</sub> H <sub>10</sub> O <sub>5</sub>     | CO <sub>2</sub> + H <sub>2</sub> O liquid | 4228            | 685.0            | B           |
| Cellulose C <sub>6</sub> H <sub>10</sub> O <sub>5</sub>  | CO <sub>2</sub> + H <sub>2</sub> O liquid | 4208            | 682.0            | B           |
| Dextrose C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>   | CO <sub>2</sub> + H <sub>2</sub> O liquid | 3762            | 677.0            | B           |
| Cane sugar C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> | CO <sub>2</sub> + H <sub>2</sub> O liquid | 3963            | 1355.0           | B           |
| Stearic acid   | CO <sub>2</sub> + H <sub>2</sub> O liquid | 9374            | —                | St          |
| Rhombic sulphur  | SO <sub>2</sub>                           | 2221            | 71.08            | F           |
| Rhombic sulphur  | SO <sub>2</sub>                           | 2166            | 69.3             | B           |
| Monoclinic sulphur                                       | SO <sub>2</sub>                           | 2241            | 71.72            | Th          |
| Carbon disulphide  | CO <sub>2</sub> + SO <sub>2</sub>         | 3333            | 253.0            | B           |
| Silicon  | SiO <sub>2</sub>                          | 7407            | 207.4            | B           |
| Magnesium  | MgO                                       | 6077            | 145.9            | T           |
| Iron   | Fe <sub>2</sub> O <sub>3</sub>            | 1582            | 88.4             | A           |
| Copper   | CuO                                       | 590             | 37.2             | T           |

\* The heat required to evaporate 1 kilogram of water at 0°C. is 606.5 calories K.

One kilogram of coal yields approximately 7500 Cal. As one kilogram of water requires 636 Calories (K) in order to raise to 100° C and convert it into steam, it follows that  $\frac{7500}{636} = 11.79$

kilograms of water should be evaporated by one kilogram of coal. In practice with a cylindrical boiler only about 6.5 kilograms, and with the best tube boiler 10 kilograms of steam are obtained.

When employing gaseous fuels much higher efficiencies can be obtained. By means of a surface combustion boiler Prof. Bone has obtained over 95% of the total heat from the fuel.

The overall thermal efficiency of an engine is the proportion which the heat converted into work bears to the total heat entering the engine.

The thermal efficiency ( $\mu$ ) of an engine which consumes  $x$  lbs. of fuel of calorific power  $W$  for each horse power hour is obtainable by the formula :

$$\mu = \frac{2,545}{Wx}$$

The overall thermal efficiencies of various types of engines when working under favourable conditions are approximately as follows :

|                                       |        |     |
|---------------------------------------|--------|-----|
| Reciprocating steam engine and boiler | ..     | 12% |
| Steam turbine and boiler              | ... .. | 18% |
| Petrol engine (automobile)            | ... .. | 22% |
| Gas engine with producers             | ... .. | 24% |
| Gas engine with suction producer      | ... .. | 26% |
| Petrol engine (aircraft)              | ... .. | 27% |
| Semi-Diesel oil engine                | ... .. | 30% |
| Alcohol engine                        | ... .. | 36% |
| Diesel oil engine                     | ... .. | 38% |

## MISCELLANEOUS DATA CONCERNING FUELS.

| Fuel                 | P       | Sp. Gr.   | Composition in parts per thousand |      |     |     |     |      | Q     | L    | G   | V    |
|----------------------|---------|-----------|-----------------------------------|------|-----|-----|-----|------|-------|------|-----|------|
|                      |         |           | C                                 | H    | O   | W   | R   | i    |       |      |     |      |
| Air dried wood       | 350-450 | 0.6-0.8   | 400                               | 40   | 320 | 200 | 40  | 0.25 | 2900  | 5.0  | 12  | 0.70 |
| Air dried peat       | 250-400 | 0.4-0.5   | 420                               | 45   | 225 | 250 | 60  | 0.35 | 3600  | 5.6  | 12  | 0.74 |
| Lignite              | .. ..   | .. ..     | 700                               | 50   | 200 | -   | 50  | 0.42 | 6400  | 9.3  | 20  | 0.42 |
| Bituminous coal      | 750-880 | 1.20-1.35 | 870                               | 50   | 40  | -   | 40  | 0.5  | 8300  | 11.0 | 23  | 0.31 |
| Low grade anthracite | .. ..   | .. ..     | 850                               | 50   | 60  | -   | 40  | 0.32 | 8100  | 10.7 | 22  | 0.32 |
| Dry coal             | .. ..   | .. ..     | 750                               | 50   | 150 | -   | 50  | 0.39 | 6900  | 10.1 | 21  | 0.39 |
| Anthracite           | 900     | 1.35-1.46 | 900                               | 30   | 30  | -   | 40  | 0.19 | 8000  | 11.7 | 24  | 0.19 |
| Carbonised peat      | 200-350 | -         | 800                               | -    | -   | -   | 200 | 0.5- | 6500  | 9.6  | 20  | -    |
| Wood charcoal        | 230-250 | -         | 930                               | -    | -   | -   | 70  | 0.55 | 7500  | 11.2 | 23  | -    |
| Coke                 | 400-440 | -         | 880                               | -    | -   | -   | 120 | -    | 8080  | 10.6 | 22  | -    |
| Hydrogen             | 0.09    | -         | -                                 | 1000 | -   | -   | -   | -    | 28800 | 36.0 | 44  | 5.6  |
| Methane              | 0.72    | -         | 750                               | 250  | -   | -   | -   | -    | 12066 | 18.0 | 19  | 1.4  |
| Ethylene             | 1.26    | -         | 860                               | 140  | -   | -   | -   | -    | 11293 | 15.4 | 19  | 0.8  |
| Illuminating gas     | 0.696   | -         | 560                               | 370  | -   | -   | -   | -    | 10600 | 20.0 | 25  | 2.07 |
| Blast furnace gas    | 1.0     | -         | 60                                | 20   | -   | -   | -   | -    | 1070  | 1.0  | 2.2 | 0.11 |
| Carbon monoxide      | 1.26    | -         | 430                               | -    | 570 | -   | -   | -    | 2403  | 5.2  | -   | -    |

P=weight of one cubic metre in kilograms.

i=coefficient of radiation.

G=weights of products of combustion in kilograms.

W=hygroscopic water.

Q=gross calorific value.

R=inorganic residue.

L=theoretical quantity of air required in kilograms.

V=increase in volume in ccs.



## THE SAMPLING AND ANALYSIS OF COAL.

### *Sampling.*

The greatest care must be taken in sampling. One spadeful of coal from each truck is taken, and the heap divided into four sections; two diagonally opposite portions are taken and the process is repeated until about one cwt. remains, when the coal is broken into small pieces (about  $\frac{1}{2}$ -inch cube). The parting process is continued until about 10 lbs. remain, the pieces broken up and then about 2 lbs. withdrawn for the finished sample. This sample is then ground to pass through a 60's mesh sieve.

### *Analysis.*

#### (1) *Moisture.*

30 to 50 grams of coal are taken in a weighing bottle and dried in a steam-jacketed oven at  $105^{\circ}\text{C}$ . When the weight becomes constant the water may be considered as completely driven off. Sometimes the weight will begin to increase, due to the absorption of oxygen from the air. In this case the minimum weight is to be taken.

#### (2) *Ash.*

About 1 gram of coal is ignited in a platinum crucible until the weight becomes constant (the process may take several hours).

#### (3) *Sulphur.*

This is best determined in the bomb liquor from the calorimeter determination. The liquor is first oxidised with an excess of bromine water. After driving off the excess of bromine by boiling, the sulphur may be estimated by precipitation as barium sulphate. The sulphur may also be estimated by the direct titration of the bomb liquor (after boiling to expel  $\text{CO}_2$ ) with N/10 caustic soda solution, employing methyl orange as indicator. In this case a slight error is introduced due to the presence of traces of nitric acid formed during the combustion.

In cases where the bomb calorimeter is not employed it is usual to resort to fusion, as follows:

1 gram of powdered coal and 1.5 to 2 grams of a mixture of 2 parts magnesia and one part sodium carbonate are heated in a platinum crucible, the mass being continually gently stirred. The colour will become bright yellow or brown, when the contents of the crucible may be dissolved in boiling water, and any remaining sulphides oxidised by the addition of bromine water. The solution is filtered, the filtrate acidified with

hydrochloric acid, boiled until colourless, and then precipitated with barium chloride.

For the estimation of sulphur present as sulphate ( $\text{CaSO}_4$ ) or sulphide ( $\text{FeS}_2$ ), 1 gram of the powdered coal is heated with a saturated solution of bromine in caustic soda (Sp. Gr. 1.25), and the solution acidified with hydrochloric acid, treated with 20 cc. of bromine solution, heated and acidified, and the process repeated.

The solution is evaporated to dryness at  $110^\circ\text{C}$ . in order to render the silica insoluble, extracted with hydrochloric acid and the filtrate precipitated with barium chloride.

The sulphates may be determined in the ash. About 3 grams of ash are taken, mixed with water and heated with hydrogen peroxide or bromine, then acidified and precipitated with barium chloride.

#### (4) *Combustion.*

The combustion is carried out by the usual method employed for organic bodies. It is, however, necessary to pack the tube with lead chromate in order to retain the sulphur dioxide formed by the combustion of the sulphur.

#### (5) *Nitrogen.*

0.8 to 1 gram of the fine coal is taken and the nitrogen estimated by the Kjeldahl method (see Vol. I.).

#### (6) *Coke Yield.*

1 gm. of powdered coal is strongly heated for 7 mins. over a Bunsen flame 20 cm. high, in a platinum crucible 35 mm. deep and 22 mm. wide, the bottom of the crucible being 6—8 cm. from the top of the burner. The crucible is provided with a tight fitting lid, in the centre of which is a 2 mm. hole. The crucible and contents are allowed to cool for a period of 5—10 mins. and then weighed.

An alternative method is to heat the crucible in a muffle furnace until one minute after the last flame has disappeared.

#### (7) *Volatile matter.*

The volatile matter is estimated by difference from coke yield.

#### (8) *Coking power.*

This is also only a comparative test. The powdered coal is mixed with Calais sand to give a total weight of 25 gm. The mixture is heated as noted in the first method described for the estimation of volatile matter. The proportions of coal and sand are adjusted so that the button obtained will just bear a 100 gm. weight without being crushed. The coking power is the ratio of sand to coal. (The degree of fineness of the sand has a serious influence on the results of this test.)



# Analyses of Coals. (Gray and Robinson).

663

|                        | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    |
|------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Carbon .. .. .         | 62.55 | 65.50 | 68.64 | 69.50 | 72.14 | 73.77 | 74.99 | 74.57 | 77.00 | 76.71 | 78.80 | 85.70 |
| Hydrogen .. .. .       | 3.87  | 4.23  | 4.33  | 4.42  | 4.40  | 4.55  | 4.66  | 4.74  | 4.51  | 4.67  | 4.92  | 2.97  |
| Sulphur .. .. .        | 1.62  | 0.67  | 1.33  | 0.67  | 0.61  | 0.41  | 0.55  | 0.47  | 0.78  | 0.73  | 0.50  | 0.62  |
| Water .. .. .          | 8.63  | 7.92  | 8.96  | 9.28  | 8.34  | 7.99  | 7.21  | 6.95  | 2.31  | 1.94  | 2.72  | 3.15  |
| Ash .. .. .            | 11.78 | 10.15 | 6.90  | 5.97  | 4.22  | 1.76  | 2.68  | 1.37  | 7.17  | 8.49  | 4.18  | 3.59  |
| Oxygen and Nitrogen .. | 11.55 | 11.53 | 9.84  | 10.16 | 10.29 | 11.52 | 9.91  | 11.90 | 8.23  | 7.46  | 8.88  | 3.90  |
| Coke .. .. .           | 61.74 | 61.06 | 57.53 | 59.12 | 58.47 | 56.93 | 56.59 | 56.84 | 74.61 | 72.32 | 66.43 | 92.03 |
| Fixed Carbon .. .. .   | 49.96 | 50.92 | 50.63 | 53.15 | 54.25 | 55.17 | 53.91 | 55.47 | 67.44 | 63.83 | 62.25 | 88.44 |

1. Splint coal, Lochgelly, Fife.
2. Boiler fuel (a mixture), Fife.
3. Ell coal, Bothwell.
4. Main coal, Bothwell.
5. Poytshaw coal, Bothwell.
6. Dunfermline splint, Cowdenbeath, Pit 10.
7. Splint coal, Bothwell.
8. Dunfermline splint, Cowdenbeath Pit 7.
9. Boiler fuel, Aitken Pit, Kilty.
10. Haughrigg coking coal, Kilsyth.
11. Coking coal, Kilsyth.
12. Anthracite, Kilsyth.

PROPERTIES OF VARIOUS TYPES OF COAL.

| Description                                     | Composition (%) |         |          |     | Specific gravity | Calorific power calories | Evaporative power | Volatile portion | Coke yield                                    |
|---|-----------------|---------|----------|-----|------------------|--------------------------|-------------------|------------------|---|
|   | C               | H       | O        | H   |                  |                          |                   |                  |   |
| 1. Dry coal with long flame<br>(Sand coal.)     | 75-80           | 5.5-4.5 | 19.5-15  | 4-3 | 1.25             | 8000-8500                | 6.7-7.5           | 45-50            | 50-60<br>(powdery)                            |
| 2. Long flame fat coal<br>(Gas or sinter coal.) | 80-85           | 5.8-5   | 14.2-10  | 3-2 | 1.28-1.3         | 8500-8800                | 7.6-8.3           | 40-32            | 60-80<br>(fused,<br>intumesced)               |
| 3. Fat or furnace coal..                        | 84-89           | 5-5.5   | 11.5-5.5 | 2-1 | 1.3              | 8800-9300                | 8.4-9.2           | 32-26            | 68-74<br>(moderately<br>dense, fused)         |
| 4 Fat coal with short flame<br>(Coking coal.)   | 88-91           | 5.5-4.5 | 6.5-5.5  | 1   | 1.3-1.35         | 9300-9600                | 9.2-10            | 26-18            | 74-82<br>(fused,<br>compact and<br>blistered) |
| 5. Short flame coal ..<br>(Anthracite.)         | 90-93           | 4.5-4   | 5.5-3    | 1   | 1.35-1.4         | 9200-9500                | 9. -9.5           | 18-10            | 82-90<br>(sintered<br>or powdery)             |

|                     | COKE ANALYSES. |         |          |           | COAL ANALYSES. |         |         |          |
|---------------------|----------------|---------|----------|-----------|----------------|---------|---------|----------|
|                     | True Apparent  |         | % cells, |           | Volatile       |         | Fixed   |          |
|                     | Moisture.      | Sp. Gr. | % cells  | Wt., lbs. | Moisture.      | Sp. Gr. | matter. | Sulphur. |
|                     |                |         | by vol.  | per       |                |         | carbon. |          |
|                     |                |         | 100 gm.  | cu. ft.   |                |         |         |          |
| Broadford, Con-     |                |         |          |           |                |         |         |          |
| nellsville, Pa. . . | 0.034          | 1.76    | 0.892    | 49.37     | 55.68          | 1.10    | 29.88   | 57.75    |
| Connellsville, Pa.  | 0.053          | 1.74    | 0.926    | 46.92     | 57.81          | —       | 31.86   | 59.62    |
| Eagle, Kanawha,     |                |         |          |           |                |         |         |          |
| W. Va. . . . .      | 0.021          | 1.68    | 0.894    | 46.85     | 55.81          | —       | —       | —        |
| St. Clair, Kanawha, |                |         |          |           |                |         |         |          |
| W. Va. . . . .      | 0.030          | 1.67    | 0.924    | 44.81     | 57.68          | —       | —       | —        |
| Quinnimont,         |                |         |          |           |                |         |         |          |
| New River . . .     | 0.044          | 1.83    | 0.713    | 61.12     | 44.51          | 0.41    | 19.99   | 76.87    |
| Sewell, New         |                |         |          |           |                |         |         |          |
| River, W. Va. . .   | 0.016          | 1.69    | 0.793    | 53.19     | 49.50          | 1.03    | 21.38   | 72.32    |
| Stone Cliff, New    |                |         |          |           |                |         |         |          |
| River, W. Va. . .   | 0.074          | 1.74    | 0.838    | 51.79     | 52.31          | —       | —       | —        |
| Five Creek, New     |                |         |          |           |                |         |         |          |
| River, W. Va. . .   | 0.078          | 1.83    | 0.820    | 55.12     | 51.19          | 0.61    | 22.34   | 75.02    |
| Rockwood, Tenn.     | 0.192          | 1.69    | 0.935    | 44.81     | 58.37          | 1.75    | 26.62   | 60.11    |
| El Moro, Col. . . . | 0.114          | 1.69    | 0.919    | 45.75     | 57.37          | 1.14    | 29.97   | 56.32    |
| Crested Butte, Col. | 0.073          | 1.59    | 0.907    | 42.96     | 56.62          | 0.72    | 23.44   | 71.91    |
| Leetonia, Ohio . .  | 0.047          | 1.49    | 0.770    | 47.59     | 48.09          | 3.00    | 31.50   | 62.35    |
| Washington,         |                |         |          |           |                |         |         |          |
| D.C. . . . .        | 0.802          | 1.74    | 0.772    | 55.66     | 48.19          | —       | —       | —        |

\* Bacon and Hamar, "American Fuels," 1922.

# Analyses of American By-Product Coke: (Koppers Co.)\*

| COAL ANALYSES.   |                  |       |          |                             | COKE ANALYSES. |                  |               |       |          |
|------------------|------------------|-------|----------|-----------------------------|----------------|------------------|---------------|-------|----------|
|                  | Volatile matter. | Ash   | Sulphur. | % through $\frac{1}{8}$ in. |                |                  |               |       |          |
|                  |                  |       |          |                             | Moisture.      | Volatile matter. | Fixed carbon. | Ash.  | Sulphur. |
| Alabama (washed) | 29.3             | 7.38  | 1.39     | —                           | 9.52           | 1.15             | 89.95         | 8.90  | 1.17     |
| Alabama (washed) | 28.4             | 8.80  | 0.79     | 74.8                        | 7.42           | 0.50             | 88.74         | 10.76 | 0.64     |
| Colorado         | 33.1             | 12.63 | 0.68     | —                           | 4.00           | 1.86             | 81.86         | 16.28 | 0.57     |
| Pennsylvania     | 25.4             | 5.85  | 0.87     | 67.6                        | 4.50           | 0.73             | 90.49         | 8.78  | 0.78     |
| Washington       | 31.5             | 11.31 | 0.50     | 45.0                        | 2.85           | 1.16             | 84.91         | 13.93 | 0.47     |
| 80% W. Va.       | 21.0             | 8.12  | 0.87     | 84.0                        | 3.61           | 2.07             | 86.41         | 11.52 | 0.73     |
| 20% Ill.         |                  |       |          |                             |                |                  |               |       |          |
| 80% W. Va.       | 21.5             | 7.97  | 0.79     | 84.5                        | 9.55           | 1.06             | 88.77         | 10.17 | 0.69     |
| 20% Pa.          |                  |       |          |                             |                |                  |               |       |          |
| 70% W. Va.       | 23.1             | 6.34  | 0.63     | 86.0                        | 5.20           | 1.95             | 89.64         | 8.41  | 0.66     |
| 30% Ky.          |                  |       |          |                             |                |                  |               |       |          |
| 40% W. Va.       | 29.3             | 5.48  | 0.52     | —                           | 2.56           | 1.34             | 89.72         | 8.94  | 0.49     |
| 60% Ky.          |                  |       |          |                             |                |                  |               |       |          |
| 40% W. Va.       | 28.9             | 6.73  | 0.77     | 85.0                        | 4.48           | 1.47             | 88.31         | 10.21 | 0.67     |
| 60% Pa.          |                  |       |          |                             |                |                  |               |       |          |

666

666

\* Bacon and Hamar, "American Fuels," 1922.

## The Examination of Liquid Fuels.

The more important tests employed for the examination of liquid fuels depend upon their physical properties. For a full understanding of the fuel, it is also necessary to consider the chemical analysis.

*Specific Gravity.* The specific gravity of a liquid fuel may be determined by means of a hydrometer, specific gravity bottle, pyknometer or Mohr's balance. The temperature of the liquid must be taken into consideration. (The coefficient of cubical expansion of petroleum is '0004 per degree Fahrenheit or '00072 per degree Centigrade).

*Flash point.* The determination of the flash point of a liquid fuel may be made in an open basin or in one of the special instruments designed for this purpose. When the flash point is determined by means of an open basin it is usual to call the value the "open flash point," with the closed instruments it is referred to as the "closed flash point." For liquids which flash at temperatures below 100°C. the Abel apparatus is generally employed. When determining the flash point the instrument is heated slowly, the small flame on the cover being adjusted to the correct size, which is indicated by a small ivory knob attached to the cover. The test flame is dipped periodically until a small flame is observed to travel across the surface of the liquid. The liquid must be stirred continually during the test in order to prevent local overheating. The temperature reading on the thermometer in the inner vessel, when the flash is first observed, indicates the flash point.

Many modifications of the Abel apparatus exist, the best known being the Pensky Marten and the Gray instruments, both of which are adapted for the testing of "high flash" fuel and lubricating oils, the main difference between these and the original instrument being that in place of a water jacket they are provided with a cast-iron casing, thus enabling the temperature to be carried above the boiling point of water.

### *Temperature of Spontaneous Ignition or Ignition Point.*

This test is of great importance with liquid fuels for internal combustion. It is of secondary interest in connection with solid fuels.

The determination is most satisfactorily made by means of Moore's ignition point tester (*J.S.C.I.*, 1917, p. 109). The instrument consists of a large block of metal into which are fitted a pyrometer thermocouple, a thermal plug for pre-heating the oxygen supply, and a platinum or nickel crucible of standard dimensions. The block is heated by a burner, and a current of dry oxygen slowly passed through the crucible. Oil is dropped into the crucible from a thin glass tube. If the temperature of the block as shown by the pyrometer is above the ignition point a sharp explosion follows shortly after the introduction of the oil. The lowest temperature at which the oil will ignite is the "ignition point."

*Viscosity* Several instruments are employed for the determination of viscosity. In England the Redwood viscometer is the standard appliance. On the Continent the Engler viscometer is used, whilst in the United States the Saybolt instrument is generally employed.

In order to determine the viscosity of a liquid, the viscometer is filled to the pointer, and the liquid heated to the required temperature by means of a Bunsen burner. When the temperature is attained the Bunsen burner is withdrawn or adjusted as is necessary to maintain the temperature. The ball valve is now withdrawn, allowing the liquid to discharge into a 50 cc. graduated cylinder. The time required to discharge 50 cc. of the oil is proportional to the viscosity. It is usual to state the results in terms of Redwood's units, which are based on refined rape oil, the viscosity of this liquid being considered as 100 units. In calculating this value it is necessary to correct for the specific gravity, to which the pressure upon the diaphragm is proportional.

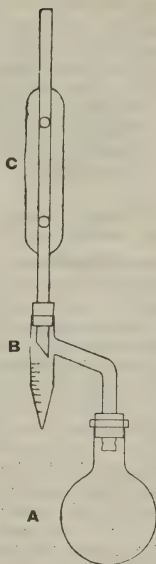
*Water.* This may be estimated by several methods; in the case of tar products or tars, it is usual to heat the liquid slowly in a retort and receive the water and a small amount of oil in a small graduated cylinder. On addition of a few cc. of toluene to the distillate, the water settles out at the bottom of the cylinder and the volume can be read off directly. This method can be used with petroleum. Another means of estimating water is to mix a measured quantity of the oil with toluene and distil from a Wurtz flask, condensing the distillate and collecting in a graduated cylinder. For this estimation Schlöpfer has designed a special cylinder, the lower portion of which is of reduced diameter, thus enabling more accurate readings of the water yield to be made.



The best method for the determination of water is the one recently described by Dr. E. W. Dean and D. D. Stark. For this test the apparatus consists of a 500 cc. short-necked distilling flask, A and a "distilling tube receiver" B, to the upper end of which is connected a Liebig's condenser C, the tube of which is ground off diagonally at the bottom end, to facilitate the dropping of the water into the measuring tube.

To make a determination, 100 cc. of the emulsion to be tested and 100 cc. of a solvent, such as petroleum ether, or a mixture of commercial xylol and commercial benzol, are introduced into the 500 cc. flask together with a fragment of unglazed porcelain, and the flask connected to the distilling tube receiver and condenser, the position of the diagonally-ground end of tube being as shown in sketch

Heat is applied to the flask so as to cause the mixture to distill at a rate of two to four drops per second, till all droplets of water in flask, distilling tube and condenser have disappeared, which usually takes about an hour. In case a ring of droplets appears in condenser the rate of distillation may be increased till it is swept away. The flask is then detached, and the volume of water collected in the graduated receiver is read off, taking care that the receiver shall be held in a vertical position.



*Coke Test.* 100 cc. of the oil under examination are measured into a weighed Engler distillation flask, and the weight of the oil found by difference. The oil is then fractionally distilled until the temperature of the vapours is  $300^{\circ}\text{C}$ . (temperature corrected for exposed stem).

The residue in the flask is poured while hot into a 300 cc. silica beaker provided with a lid having a small central orifice. The distillation of the material in the beaker is then completed over a radial burner, the escaping vapours being carried off by the fume exhaust. Towards the end of the experiment the heating is greatly increased, the beaker being placed over the naked flame so that its base is at bright red heat, and the

flames surround the beaker so as to form an enveloping flame bath. This is continued for one minute after all visible vapours from the residue have ceased. The beaker is now cooled, and the slight amount of condensed tar on its upper internal surface burned off. The coke remains as a bright porous basal cake, detachable with ease from the silica beaker. It is then cooled in a desiccator and weighed.

Weight of oil used in grams = X.

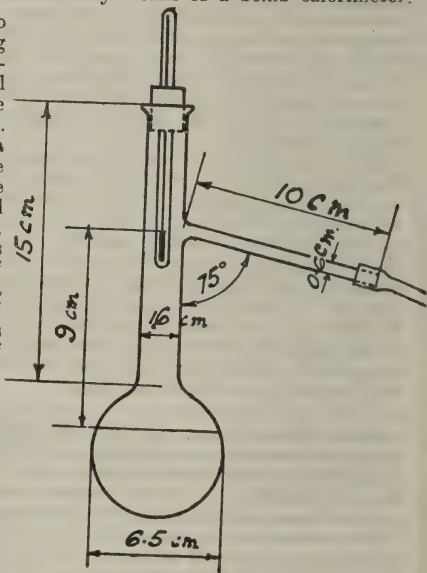
Volume of water obtained in distillation in cc. = Y.

Weight of coke in grams = A.

Percentage of coke in dry oil =  $\frac{A \times 100}{X - Y}$

*Calorific power.* The calorific power of liquid fuels can only be satisfactorily ascertained by means of a bomb calorimeter.

*Distillation test.* To determine the boiling points of the constituent compounds in an oil it is necessary to make a fractional distillation. For this purpose a distillation flask of the special dimensions (see sketch) recommended by Engler is employed. The thermometer is placed in the neck of the flask in such a position that the top of the thermometer bulb is level with the bottom of the side tube. 100 cc. of the liquid is distilled at the rate of two drops per second and the quantity of distillate noted every 10°. The results are best recorded by drawing a graph showing the percentage volume of distillate as a function of the temperature.



ENGLER FLASK.

A fractionating column may be employed in special cases, but the Engler method above described is more frequently used.



*Asphaltum.* This substance may be estimated either by evaporating the liquid in an open basin and weighing residue or by the following more satisfactory method :

5 grm. of oil are weighed into a beaker and dissolved in 25 times its volume of ethyl ether at  $15^{\circ}\text{C}.$ ; 96% alcohol to the extent of  $12\frac{1}{2}$  times the volume of the oil is now slowly added from a burette, the liquid being stirred continuously. After 5 hours standing at  $15^{\circ}\text{C}.$  the product is filtered and the filter washed with alcohol-ether mixture (1:2). The precipitate is then dissolved in benzene and the solution evaporated down in a tared dish. After repeated washing with hot alcohol, until no further precipitate of paraffin separates from the alcohol, the residue is heated to  $105^{\circ}\text{C}.$  for 15 minutes, cooled and weighed.

This test is known as the soft asphaltum test. Another test, which gives different results from the above, is known as the hard asphaltum test, the procedure in this test being as follows :

Two to five grams of an asphaltic oil, or 20 grams of an oil which is poor in asphaltum, are weighed into a one-litre flask with forty times their volume of petrol, and the mixture well shaken. The solution is filtered, and the residue washed with petrol until the filtrate on evaporation leaves no residue of oil. The precipitate is now dissolved in benzene, and the solution evaporated at  $100^{\circ}\text{C}.$  in a tarred dish.

Both these tests are applied to petroleum oils, but distilled products are free from asphaltum, therefore the test only applies to crude oils, de-petrolised crude oils, and residua.

*Tar Acids.* The tar acids, which mainly consist of phenol and the cresols, are determined in tar products by washing the liquid with caustic soda ( $40^{\circ}\text{Tw}.$ ), separating the solution (which contains the sodium salts of phenol and cresol together with free caustic soda), and acidifying the solution with sulphuric acid, when the mixed tar acids will separate from the solution. The volume of tar acids can thus be read directly by acidifying the solution in a graduated cylinder. It is usual to state the result as percentage by volume.

*Cold test.* The determination of the solidification point, or cold test, of liquid fuels is occasionally made. It is however preferable to cool to some definite temperature and describe the condition of the oil.

#### *Ultimate Analysis.*

The carbon, hydrogen, ash, and coke contents are determined by the usual method employed for organic substances.

Sulphur is best estimated in the liquor which condenses in the calorimeter bomb by oxidising with bromine water and precipitating as barium sulphate.

# COMPOSITION AND CALORIFIC PROPERTIES OF SEVERAL SOLID AND LIQUID FUELS.

(Determined by MAHUEB by means of Bomb Calorimeter.)

| Description and Origin          | Chemical composition |       |      |      | Hygroscopic<br>water | Ash  | Volatile<br>portion<br>without<br>water | Calorific Power |                           |
|---------------------------------|----------------------|-------|------|------|----------------------|------|---|-----------------|---------------------------|
|                                 | % C                  | % H   | % O  | % N  |                      |      |   | Observed        | Without<br>ash &<br>water |
| Long flame coal, Blancy .. ..   | 79.38                | 4.97  | 8.72 | 1.13 | 3.90                 | 1.00 | 30.10                                   | 7865            | 8350                      |
| Gas coal, Commentry .. ..       | 80.18                | 5.24  | 7.19 | 0.98 | 3.00                 | 3.40 | 37.30                                   | 7870            | 8408                      |
| Gas coal, Lens .. ..            | 83.73                | 5.25  | 6.01 | 1.00 | 1.25                 | 3.00 | 29.55                                   | 8395            | 8744                      |
| Fat coal, St. Etienne .. ..     | 84.55                | 4.77  | 4.59 | 0.84 | 1.05                 | 4.00 | 19.75                                   | 8991            | 8856                      |
| Anthracite, Tonkin .. ..        | 85.75                | 2.73  | 2.67 | 0.60 | 2.80                 | 5.45 | 4.56                                    | 7828            | 8532                      |
| Anthracite, Pennsylvania .. ..  | 86.46                | 2.00  | 1.45 | 0.75 | 4.45                 | 5.90 | 2.75                                    | 7484            | 8256                      |
| Petroleum coke, America .. ..   | 97.85                | 0.49  | 1.20 | 0.26 | -                    | 0.20 | -                                       | 8057            | 8073                      |
| Heavy naphtha, Pennsylvania ..  | 86.89                | 13.11 | -    | -    | -                    | -    | -                                       | 10912           | 10912                     |
| Refined Petroleum, America ..   | 85.49                | 14.22 | 0.29 | -    | -                    | -    | -                                       | 11045           | -                         |
| Petroleum spirit, America .. .. | 80.58                | 15.10 | 4.32 | -    | -                    | -    | -                                       | 11086           | -                         |
| Crude petroleum .. ..           | 83.01                | 13.84 | 3.10 | -    | -                    | -    | -                                       | 11094           | -                         |
| Heavy naphtha, Baku .. ..       | 86.70                | 12.94 | -    | -    | -                    | 0.30 | -                                       | 10804           | 10842                     |
| Heavy naphtha, Novorossisk ..   | 84.91                | 11.54 | 9.46 | -    | -                    | -    | -                                       | 10328           | -                         |



# Flash Points, Burning Points and Temperatures of Spontaneous Ignition. (Constam and Schläpfer).

| Description.                    | Specific Gravity at 15°C. | Open Flash Point. °C. | Burning Point. °C. | Temp. of Spontaneous Ignition. °C. |
|---------------------------------|---------------------------|-----------------------|--------------------|------------------------------------|
| Crude oil from Galicia .. ..    | .855                      | 98                    | 118                | 350                                |
| Gas oil from Galicia .. ..      | .868                      | 96                    | 149                | 350                                |
| Roumanian gas oil .. .. .       | .892                      | 87                    | 106                | 350                                |
| Russian crude oil .. .. .       | .902                      | 95                    | 122                | 350                                |
| Texas gas oil .. .. .           | .892                      | 86                    | 103                | 350                                |
| Mexican crude oil .. .. .       | .940                      | 58                    | 94                 | 350                                |
| Scotch crude oil (shale oil) .. | .942                      | 102                   | 114                | 350                                |
| African palm oil .. .. .        | .915                      | 244                   | 263                | 400                                |
| Coal tar oil .. .. .            | 1.043                     | 67                    | 84                 | 550                                |
| Horizontal retort tar .. ..     | 1.138                     | 71                    | 97                 | 520                                |
| Inclined retort tar .. .. .     | 1.157                     | 68                    | 74                 | 500                                |
| Vertical retort tar .. .. .     | 1.057                     | 74                    | 95                 | 520                                |
| Coke oven tar .. .. .           | 1.140                     | 92                    | 108                | 600                                |
| Water gas tar .. .. .           | .968                      | 92                    | 96                 | under 350°                         |

## Flash Point Corrections for Barometric Pressure.

| mm. | Flash Points °C. |      |      |      |      |      |      |      |      |      |      |      |      |
|-----|------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| 685 | 16.4             | 16.9 | 17.4 | 17.9 | 18.4 | 18.9 | 19.4 | 19.9 | 20.4 | 20.9 | 21.4 | 21.9 | 22.4 |
| 690 | 16.6             | 17.1 | 17.6 | 18.1 | 18.6 | 19.1 | 19.6 | 20.1 | 20.6 | 21.1 | 21.6 | 22.1 | 22.6 |
| 695 | 16.7             | 17.2 | 17.7 | 18.2 | 18.7 | 19.2 | 19.7 | 20.2 | 20.7 | 21.2 | 21.7 | 22.2 | 22.7 |
| 700 | 16.9             | 17.4 | 17.9 | 18.4 | 18.9 | 19.4 | 19.9 | 20.4 | 20.9 | 21.4 | 21.9 | 22.4 | 22.9 |
| 705 | 17.1             | 17.6 | 18.1 | 18.6 | 19.1 | 19.6 | 20.1 | 20.6 | 21.1 | 21.6 | 22.1 | 22.6 | 23.1 |
| 710 | 17.3             | 17.8 | 18.3 | 18.8 | 19.3 | 19.8 | 20.3 | 20.8 | 21.3 | 21.8 | 22.3 | 22.8 | 23.3 |
| 715 | 17.4             | 17.9 | 18.4 | 18.9 | 19.4 | 19.9 | 20.4 | 20.9 | 21.4 | 21.9 | 22.4 | 22.9 | 23.4 |
| 720 | 17.6             | 18.1 | 18.6 | 19.1 | 19.6 | 20.1 | 20.6 | 21.1 | 21.6 | 22.1 | 22.6 | 23.1 | 23.6 |
| 725 | 17.8             | 18.3 | 18.8 | 19.3 | 19.8 | 20.3 | 20.8 | 21.3 | 21.8 | 22.3 | 22.8 | 23.3 | 23.8 |
| 730 | 18.0             | 18.5 | 19.0 | 19.5 | 20.0 | 20.5 | 21.0 | 21.5 | 22.0 | 22.5 | 23.0 | 23.5 | 24.0 |
| 735 | 18.1             | 18.6 | 19.1 | 19.6 | 20.1 | 20.6 | 21.1 | 21.6 | 22.1 | 22.6 | 23.1 | 23.6 | 24.1 |
| 740 | 18.3             | 18.8 | 19.3 | 19.8 | 20.3 | 20.8 | 21.3 | 21.8 | 22.3 | 22.8 | 23.3 | 23.8 | 24.3 |
| 745 | 18.5             | 19.0 | 19.5 | 20.0 | 20.5 | 21.0 | 21.5 | 22.0 | 22.5 | 23.0 | 23.5 | 24.0 | 24.5 |
| 750 | 18.7             | 19.2 | 19.7 | 20.2 | 20.7 | 21.2 | 21.7 | 22.2 | 22.7 | 23.2 | 23.7 | 24.2 | 24.7 |
| 755 | 18.8             | 19.3 | 19.8 | 20.3 | 20.8 | 21.3 | 21.8 | 22.3 | 22.8 | 23.3 | 23.8 | 24.3 | 24.8 |
| 760 | 19.0             | 19.5 | 20.0 | 20.5 | 21.0 | 21.5 | 22.0 | 22.5 | 23.0 | 23.5 | 24.0 | 24.5 | 25.0 |
| 765 | 19.2             | 19.7 | 20.2 | 20.7 | 21.2 | 21.7 | 22.2 | 22.7 | 23.2 | 23.7 | 24.2 | 24.7 | 25.2 |
| 770 | 19.4             | 19.9 | 20.4 | 20.9 | 21.4 | 21.9 | 22.4 | 22.9 | 23.4 | 23.9 | 24.4 | 24.9 | 25.4 |
| 775 | 19.5             | 20.0 | 20.5 | 21.0 | 21.5 | 22.0 | 22.5 | 23.0 | 23.5 | 24.0 | 24.5 | 25.0 | 25.5 |
| 780 | 19.7             | 20.2 | 20.7 | 21.2 | 21.7 | 22.2 | 22.7 | 23.2 | 23.7 | 24.2 | 24.7 | 25.2 | 25.7 |
| 785 | 19.9             | 20.4 | 20.9 | 21.4 | 21.9 | 22.4 | 22.9 | 23.4 | 23.9 | 24.4 | 24.9 | 25.4 | 25.9 |

# Spontaneous Ignition Temperatures in Oxygen and Air (Moore).

| Description.                        | Specific gravity. | Temperature of<br>spont. ignition. |         |
|-------------------------------------|-------------------|------------------------------------|---------|
|                                     |                   | In oxygen.                         | In air. |
| Crude petroleum and residua :       |                   | °C.                                | °C.     |
| Crude petroleum (Texas) .. ..       | 0·936             | 268·5                              | 416     |
| Crude petroleum (California) .. ..  | 0·961             | 262                                | 420     |
| Crude petroleum (Mexico) .. ..      | 0·949             | 258                                | 425     |
| Crude petroleum (Borneo) .. ..      | 0·939             | 269                                | 380     |
| Anglo-Persian Oil Co.'s oil .. ..   | 0·894             | 254                                | 408     |
| Petroleum distillates :             |                   |                                    |         |
| Petrol .. ..                        | 0·718             | 279                                | 361     |
| Petrolite kerosene .. ..            | 0·814             | 251·5                              | 432     |
| Taxibus motor spirit .. ..          | 0·729             | 272                                | 390     |
| Pratt's Perfection spirit, No. 1 .. | 0·710             | 272                                | 383     |
| Pratt's Perfection spirit, No. 2 .. | 0·724             | 270                                | 371     |
| Shale oil :                         |                   |                                    |         |
| Lighthouse oil .. ..                | 0·803             | 251                                | 322     |
| Oil engine oil .. ..                | 0·768             | 253                                | 333     |
| Oil gas tar distillates :           |                   |                                    |         |
| "Special distillate" of O.G. tar .. | 0·995             | 429                                | -       |
| Oil gas tar creosote .. ..          | 1·036             | 473                                | -       |
| Oil gas tar :                       |                   |                                    |         |
| Water gas tar .. ..                 | 1·080             | 445                                | -       |
| Carburetted water gas tar .. ..     | 1·053             | 445                                | -       |
| Carburetted water gas tar .. ..     | 1·078             | 437                                | -       |
| Water gas tar .. ..                 | 1·074             | 464                                | -       |
| Raw tars :                          |                   |                                    |         |
| Horizontal retort tar .. ..         | 1·114             | 445                                | -       |
| Horizontal retort tar .. ..         | 1·123             | 454                                | -       |
| Blast furnace tar .. ..             | 1·172             | 498                                | -       |
| Tar from low temp. carbonisation .. | 0·987             | 307                                | 508     |
| Vertical retort tar .. ..           | 1·102             | 474                                | -       |
| Coke oven tar (Simon-Carvé ovens)   | 1·132             | 494                                | -       |
| Coke oven tar (Hopper ovens) ..     | 1·145             | 495                                | -       |
| Coke oven tar (Coppée ovens) .. ..  | 1·140             | 488                                | -       |
| Tar distillates :                   |                   |                                    |         |
| Benzol 100's .. ..                  | 0·875             | 566                                | -       |
| Toluol 90's .. ..                   | 0·863             | 516                                | -       |
| Xylol (commercial) .. ..            | 0·860             | 484                                | -       |
| Premier Tarless Retort tar oil ..   | 0·992             | 349                                | -       |
| Paris gas works coal tar oil .. ..  | 1·080             | 449                                | -       |
| Coke oven tar oil .. ..             | 1·046             | 478                                | -       |
| Creosote oil .. ..                  | 1·010             | 415                                | -       |
| Blast furnace creosote oil .. ..    | 0·988             | 463                                | -       |
| Miscellaneous :                     |                   |                                    |         |
| Alcohol .. ..                       | 0·817             | 395                                | 518     |
| Asphaltum from petroleum oil ..     | -                 | 260                                | -       |
| Naphthalene .. ..                   | -                 | 402                                | -       |

## Limits of Inflammability of Gas Mixtures with Air.

Combustible gases or vapours in admixture with air will only propagate flame if there is sufficient, but not too much, combustible gas present in the mixture. The "lower limit" represents the least percentage, by volume, of inflammable gas, the "upper limit" the greatest percentage of inflammable gas, in mixtures which will propagate flame.

Lower limits for downward propagation of flame in a tube (Le Chatelier and Boudouard, *Compt. rend.*, 1898, **126**, 1510, *et seq.*) :—

|                   |                |                  |                |
|-------------------|----------------|------------------|----------------|
| Hydrogen .. ..    | 10.0 per cent. | Turpentine .. .. | 0.73 per cent. |
| Carbon monoxide   | 16.0 "         | Acetone .. ..    | 2.9 "          |
| Carbon disulphide | 1.94 "         | Methyl alcohol   | 6.0 "          |
| Illuminating gas  | 8.1 "          | Ethyl alcohol .. | 3.07 "         |
| Methane .. ..     | 6.0 "          | n-Propyl alcohol | 2.55 "         |
| Pentane .. ..     | 1.1 "          | i-Propyl alcohol | 2.65 "         |
| Hexane .. ..      | 1.3 "          | i-Butyl alcohol  | 1.68 "         |
| Heptane .. ..     | 1.1 "          | Allyl alcohol .. | 3.04 "         |
| Octane .. ..      | 1.0 "          | Amyl alcohol ..  | 1.19 "         |
| Nonane .. ..      | 0.83 "         | Acetic acid ..   | 4.05 "         |
| Acetylene .. ..   | 2.8 "          | Ether .. ..      | 1.9 "          |
| Amylene .. ..     | 1.6 "          | Ethyl acetate .. | 2.3 "          |
| Benzene .. ..     | 1.5 "          | Ethyl nitrate .. | 3.8 "          |
| Toluene .. ..     | 1.3 "          |                  |                |

Limits for downward propagation of flame in a Bunte burette (Eitner) :—

|                                     | Lower limit.   | Upper limit.                   |
|-------------------------------------|----------------|--------------------------------|
| Hydrogen .. ..                      | 9.45 per cent. | 66.4 per cent.                 |
| Carbon monoxide ..                  | 16.5 "         | 74.95 "                        |
| Water gas (CO + H <sub>2</sub> ) .. | 12.4 "         | 66.8 "                         |
| Methane .. ..                       | 6.1 "          | 12.8 "                         |
| Ethylene .. ..                      | 4.1 "          | 14.6 "                         |
| *Coal gas .. ..                     | 7.9 "          | 19.1 "                         |
| Acetylene .. ..                     | 3.45 "         | 52.2 "                         |
|                                     |                | (75 per cent. in large vessel) |
| Alcohol .. ..                       | 3.95 "         | 13.65 per cent.                |
| Ether .. ..                         | 2.75 "         | 7.7 "                          |
| Benzene .. ..                       | 2.65 "         | 6.5 "                          |
| Pentane .. ..                       | 2.4 "          | 4.9 "                          |
| Benzine .. ..                       | 2.4 "          | 4.9 "                          |

\* Hydrogen, 50.7 per cent.; methane, 34.3 per cent.; carbon monoxide, 7.1 per cent.; heavy hydrocarbons, 4.3 per cent.; carbon dioxide, 2.0 per cent.; nitrogen, 1.6 per cent.

Lower limits of inflammability for complete combustion of the mixture in a 2-litre globe (Burgess and Wheeler, *Journ. Chem. Soc.*, 1911, **99**, 2013) :—

|               |               |                 |                |
|---------------|---------------|-----------------|----------------|
| Methane .. .. | 5.6 per cent. | n-Butane .. ..  | 1.65 per cent. |
| Ethane .. ..  | 3.1 "         | n-Pentane .. .. | 1.37 "         |
| Propane .. .. | 2.2 "         | i-Pentane .. .. | 1.32 "         |

Lower limits for indefinite continued propagation of flame upwards, but not downwards (Coward and Brinsley, *Journ. Chem. Soc.*, 1914, **105**, 1859) :—

|                 |                |         |               |
|-----------------|----------------|---------|---------------|
| Hydrogen        | 4.1 per cent.  | Methane | 5.3 per cent. |
| Carbon monoxide | 12.5 per cent. |         |               |

# Composition, Calorific Value, etc., of Gaseous Fuels. (Brame).

| Description.                       | H, | CH, | C <sub>n</sub> H <sub>2n</sub> | Percentage Composition. |                               | B. Th. U.<br>Per C. Ft. | Air for<br>Combustion. |             |
|------------------------------------|----|-----|--------------------------------|-------------------------|-------------------------------|-------------------------|------------------------|-------------|
|                                    |    |     |                                | CO                      | Non-com-<br>bustibles. Gross. |                         | Net. Theory.           | Practice.   |
| Coal and Coke Oven Gas ..          | 50 | 33  | 3                              | 8                       | 6                             | 630                     | 550                    | 4.7 8.0     |
| Blue Water Gas ..                  | 48 | -   | -                              | 44                      | 8                             | 315                     | 290                    | 2.2 4.0 (†) |
| Producer Gas with ammonia recovery | 25 | 2   | 0.5                            | 12.5                    | 60                            | 150                     | 145                    | 1.1 1.25    |
| Producer Gas Non-Recovery ..       | 12 | 3   | 0.5                            | 24.5                    | 60                            | 170                     | 160                    | 1.2 1.25    |
| Producer Gas Coke or Anthracite .. | 16 | -   | -                              | 25                      | 59                            | 140                     | 130                    | 0.9 1.25    |
| Air Producer Gas from Coke ..      | 1  | -   | -                              | 29                      | 70                            | 105                     | 105                    | 0.75 1.0    |
| Blast Furnace Gas ..               | 1  | -   | -                              | 26.5                    | 72.5                          | 97                      | 97                     | 0.65 1.0    |



## Typical Analyses of By-Product Coke Oven Gas. (Babcock and Wilcox Co.)

| CO <sub>2</sub> | O     | CO  | CH <sub>4</sub> | H    | N    | Gross<br>B.th.u. per<br>Cubic foot. |
|-----------------|-------|-----|-----------------|------|------|-------------------------------------|
| 0.75            | Trace | 6.0 | 28.15           | 53.0 | 12.1 | 505                                 |
| 2.00            | Trace | 3.2 | 18.80           | 57.2 | 18.0 | 399                                 |
| 3.20            | 0.4   | 6.3 | 29.60           | 41.6 | 16.1 | 551                                 |
| 0.80            | 1.6   | 4.9 | 28.40           | 54.2 | 10.1 | 460                                 |

## Typical Analyses of Blast Furnace Gas. (Babcock and Wilcox.)

|                 |          |       | CO <sub>2</sub> | O    | CO    | H    | CH <sub>4</sub> | N     |
|-----------------|----------|-------|-----------------|------|-------|------|-----------------|-------|
| Bessemer        | Furnace  | .. .. | 9.85            | 0.36 | 32.73 | 3.14 | —               | 53.92 |
| Bessemer        | Furnace  | .. .. | 11.4            | —    | 27.7  | 1.9  | 0.3             | 58.7  |
| Bessemer        | Furnace  | .. .. | 10.0            | —    | 26.2  | 3.1  | 0.2             | 60.5  |
| Bessemer        | Furnace  | .. .. | 9.1             | —    | 28.7  | 2.7  | 0.2             | 59.3  |
| Bessemer        | Furnace  | .. .. | 13.5            | —    | 25.2  | 1.43 | —               | 59.87 |
| Bessemer        | Furnace* | .. .. | 10.9            | —    | 27.8  | 2.8  | 0.2             | 58.3  |
| Ferro Manganese | Furnace  |       | 7.1             | —    | 30.1  | —    | —               | 62.8† |
| Basic Ore       | Furnace  | .. .. | 16.0            | 0.2  | 23.6  | —    | —               | 60.2† |

\* Average of 20 samples.

† Includes H and CH<sub>4</sub>.



# Typical Analyses (by volume) and Calorific Values of Natural Gas. (Babcock and Wilcox Co.)

| Locality of Well.                 | H     | CH <sub>4</sub> | CO    | CO <sub>2</sub> | N     | O    | Heavy Hydrocarbons. | H <sub>2</sub> S | B.th.u. per Cubic Foot Calculated.* |
|-----------------------------------|-------|-----------------|-------|-----------------|-------|------|---------------------|------------------|-------------------------------------|
| Anderson, Ind. ....               | 1.86  | 93.07           | 0.73  | 0.26            | 3.02  | 0.42 | 0.47                | 0.15             | 1017                                |
| Marion, Ind. ....                 | 1.20  | 93.16           | 0.60  | 0.30            | 3.43  | 0.55 | 0.15                | 0.20             | 1009                                |
| Muncie, Ind. ....                 | 2.35  | 92.67           | 0.45  | 0.25            | 3.53  | 0.35 | 0.25                | 0.15             | 1004                                |
| Olean, N. Y. ....                 | —     | 96.50           | 0.50  | —               | —     | 2.00 | 1.00                | —                | 1018                                |
| Findlay, O. ....                  | 1.64  | 93.35           | 0.41  | 0.25            | 3.41  | 0.39 | 0.35                | 0.20             | 1011                                |
| St. Ive, Pa. ....                 | 6.10  | 75.54           | Trace | 0.34            | —     | —    | 18.12               | —                | 1117                                |
| Cherry Tree, Pa. ....             | 22.50 | 60.27           | —     | 2.28            | 7.32  | 0.83 | 6.80                | —                | 842                                 |
| Grapeville, Pa. ....              | 24.56 | 14.93           | Trace | Trace           | 18.69 | 1.22 | 40.60               | —                | 925                                 |
| Harvey Well, Butler Co., Pa. .... | 13.50 | 80.00           | Trace | 0.66            | —     | —    | 5.72                | —                | 998                                 |
| Pittsburgh, Pa. ....              | 9.64  | 57.85           | 1.00  | —               | 23.41 | 2.10 | 6.00                | —                | 748                                 |
| Pittsburgh, Pa. ....              | 20.02 | 72.18           | 1.00  | 0.80            | —     | 1.10 | 4.30                | —                | 917                                 |
| Pittsburgh, Pa. ....              | 26.16 | 65.25           | 0.80  | 0.60            | —     | 0.80 | 6.30                | —                | 899                                 |

\* B.th.u approximate.

## Ignition Temperatures of Gaseous Mixtures in °C at Ordinary Pressures. (Dixon and Coward).

| Gas.            | In Oxygen. | In Air.   |
|-----------------|------------|-----------|
| Hydrogen        | 580 - 590  | 580 - 590 |
| Carbon monoxide | 637 - 658  | 644 - 658 |
| Methane         | 556 - 700  | 650 - 750 |
| Ethane          | 520 - 630  | 520 - 630 |
| Ethylene        | 500 - 519  | 542 - 547 |
| Acetylene       | 400 - 440  | 406 - 440 |

# ANALYSIS OF CLAYS, FIREBRICKS, AND SILICA MATERIALS.

J. W. MELLOR, D.Sc.

## *Determination of hygroscopic moisture.*

About 5 gramm. of the finely-ground clay are dried in a toluene oven or air-bath at  $110^{\circ}$  until there is no further loss in weight; about 4 hrs. is usually sufficient.

## *Determination of loss on ignition.*

About 1 gramm. of the dry clay is heated in a platinum crucible, first over a small flame, then over a Méker or Téclu burner, and finally over a blowpipe flame for about 20 mins. The crucible is allowed to cool and weighed. The crucible and contents are again heated over the blowpipe flame for 5 mins., cooled, and weighed. Low results are usually due to the incomplete combustion of the carbon; high results may be due to losses by spurting produced by heating too rapidly.

## *Determination of silica.*

The ignited clay in the platinum crucible is intimately mixed with 10–15 gramm. of sodium carbonate. The mixture is gently heated over a Méker or Téclu burner, and finally fused at a bright red heat for 30 mins. or until the contents of the crucible are in a state of quiet fusion. The red-hot crucible is dipped in water to about two-thirds of its depth in order to solidify the contents rapidly. The cake is extracted with as small an amount of water as possible, and the washings collected in a 250 cc. basin; the cake will probably be detached from the crucible by this treatment, and is transferred to the basin. The basin is almost covered with a clock-glass, and 30 to 35 cc. of concentrated hydrochloric acid are run into the basin; the covered basin is kept warm on a water-bath until all action has subsided and the cake has disintegrated; any large pieces which remain are crushed to powder with a small agate pestle. The platinum crucible and lid are rinsed into the basin by means of hydrochloric acid and hot water. The solution is evaporated to dryness, and the contents heated in an air-oven at  $110^{\circ}$  until dry. The mass is moistened with concentrated hydrochloric acid, 60–70 cc. of hot water added, and the liquid filtered; the precipitate is washed with hot water until free from chlorides. The filtrate is returned to the basin, evaporated to dryness, and the mass is heated as before until it is free from hydrochloric acid. The residue is again digested with hydrochloric acid and about 60–70 cc. of hot water, filtered, and the residue washed with hot water until free from chlorides.

The two filter-papers are transferred to a weighed platinum

crucible, and charred slowly without flame. The carbon is burnt off slowly, and the crucible and its contents heated over the blowpipe for 15 mins. with the lid off, and then 5 mins. with the lid in position. The result is entered as "uncorrected weight of crucible and silica." The silica contains small quantities of the oxides of titanium, phosphorus, aluminium, and iron. 5 cc. of water are added to the crucible and a few drops of concentrated sulphuric acid in order to prevent, later, the volatilisation of titanous fluoride. About 15 cc. of hydrofluoric acid are carefully added a few drops at a time. The solution is cautiously evaporated to dryness on a sand-bath. The outside of the crucible is freed from sand, the crucible ignited over a burner for 5 mins., and when cool, weighed. The result is entered as "weight of crucible + residue." Later the alumina is ignited in the same crucible together with the silica residue.

#### *The ammonia precipitate.*

From 2 to 3 grm. of solid ammonium chloride and an excess of ammonia are added to the hot filtrate from the silica, and the solution filtered immediately. The precipitate is washed immediately two or three times with hot water, a hole made in the filter paper, and the precipitate washed back into the beaker from which it has just been filtered. The precipitate is redissolved in a slight excess of hydrochloric acid, and the filter paper is washed very thoroughly with hot water and kept for ignition later. The combined filtrates are heated to the boil, an excess of ammonia solution is added, the liquid filtered into the beaker previously used, and the precipitate washed free from chlorides by means of a slightly alkaline solution of ammonium nitrate (made by mixing 5 cc. of concentrated nitric acid with water, adding ammonia until alkaline, and making the solution up to a litre). The combined filtrates are evaporated to about 100 cc., and, whilst still hot, 2 to 3 cc. of ammonia are added. The liquid is filtered, and the precipitate washed free from chlorides with hot ammonium nitrate solution, care being taken that the alumina precipitate does not at any time become dry. The filtrate is reserved for the determination of lime and magnesia.

The three filter papers containing the "alumina" precipitate are dried in the platinum crucible containing the silica residue; the crucible is heated very slowly until the paper is charred, and the temperature raised until all the carbon is burnt off, finally heating for 15 mins. over a Meker burner. After weighing, the ammonia precipitate is very slowly dissolved by fusing with 5 to 6 grm. of fused potassium bi- or pyro-sulphate. The cold cake is transferred to a basin with

about 150 cc. of water, and 10 cc. of concentrated sulphuric acid are added. The mixture is heated on a water-bath until dissolved and made up to 250 cc. This solution is retained for determination of the iron and titanium.

NOTES.—(a) If the clay contains manganese, 2 or 3 cc. of bromine water are added to the solution before the ammonia precipitation, and the liquid filtered as usual. In the second precipitation 1 or 2 cc. of bromine water are again added, and the procedure is then as above described. The ammonia precipitate is washed thoroughly.

(b) In the case of a silica brick (containing over 92% of silica), where the ammonia precipitate is below 5%, only a slight excess of ammonia is added to the washings from the silica, and the excess is boiled off. The liquid is filtered, and the precipitate washed with ammonium nitrate solution as rapidly as possible.

#### *Determination of ferric oxide.*

A colorimetric process is used for materials which ignite to a white and buff colour; the ordinary permanganate process for those which give deeper colours. The colour of the sample in the crucible after it has been heated for "loss on ignition" is a good criterion to determine which process is the better. A suitable amount of the solution obtained by fusing the ammonia precipitate with pyrosulphate, etc., is made up to 250 cc. About 25 cc. are sufficient for a normal clay containing about 0.5% of ferric oxide. 5 cc. of standard iron solution (see below) is made up to 100 cc. with distilled water. The latter solution is transferred to a burette reading to 0.05 cc., and another burette is filled with distilled water. Two similar glasses are now required—the test glasses of a colorimeter can be used. Specimen glasses with parallel sides—about 3 cm. square and 8 cm. high—serve excellently. A mixture of 10 cc. of the solution to be tested with 10 cc. of potassium thiocyanate solution is made in one test glass, and in the other a mixture of 10 cc. of a solution of potash alum with 10 cc. of thiocyanate solution. The tints are viewed by light transmitted through the parallel sides of the glasses. The standard iron solution is added to the test glass with the potash alum solution and an equivalent amount of distilled water to the other, stirring thoroughly after each addition. When the tints of the liquids in the two test glasses are the same, the amount of iron oxide in the sample can be computed.

For material containing larger amounts of iron, the pyrosulphate fusion is made up to 150 cc., and 20 cc. of

concentrated sulphuric acid employed. The solution is reduced with purified zinc (about 10 grm.) until a drop sample gives no reddish-brown coloration with potassium thiocyanate. The reduced solution is made up to 250 cc., and titrated with standard potassium permanganate in the usual manner.

*Standard iron solution.* 0.6303 grm. of ferric potassium alum are dissolved in water, 5 cc. of concentrated sulphuric acid added, and the solution made up to 1 litre. 1 cc. = 0.0001 grm. of  $\text{Fe}_2\text{O}_3$ .

*Potassium thiocyanate solution.* 97 grm. of potassium thiocyanate per litre.

*Potash alum solution.* 0.05 grm. of alumina (free from iron) are fused with 5 grm. of potassium pyrosulphate, the cold cake extracted with water, 10 cc. of concentrated sulphuric acid added, and the solution made up to 1 litre.

*Determination of titanium.*

For the colorimetric determination of titanium, similar test glasses to those employed for the iron determination are used. 50 cc. of the solution of the cake from the pyrosulphate fusion are mixed with 7 to 8 cc. of hydrogen peroxide (free from fluorides), and the solution made up to 100 cc. 5 cc. of "standard titanium solution" are mixed with 5 cc. of hydrogen peroxide, and the solution made up to 100 cc. One of the test glasses is about half-filled with the solution to be tested. 10 cc. of the diluted standard titanium solution is pipetted into the other glass, and water added from a burette until the tints of the liquids in both test glasses are similar. The tints are viewed by light transmitted through the parallel sides of the test glasses. The necessary data for calculating the amount of titanium in the given sample are now available.

The weights of ferric oxide and titanous oxide in the ammonia precipitate have now been determined, and if these are subtracted from the total weight of this precipitate the difference will represent the weight of the alumina in the given sample.

*Standard titanium solution.* 1 grm. of pure titanous oxide is fused with 10 grm. potassium pyrosulphate, the cold cake extracted with cold water, and 10 cc. of concentrated sulphuric acid added. After dissolving at as low a temperature as possible, the solution is made up to 1 litre. 1 cc. = 0.001 grm. of  $\text{TiO}_2$ .

*Determination of lime.*

The filtrate from the ammonia precipitate is boiled with 1-3 grm. of ammonium oxalate, and 5-10 cc. of concentrated ammonia solution are added. The solution is agitated and allowed to stand on the water-bath for 2 hrs. The liquid is

filtered, the precipitate washed once, a hole made in the filter paper, and the precipitate washed into the beaker from which it has been filtered; the precipitate is redissolved in nitric acid, and ammonium oxalate and ammonia are added to the boiling solution as before. The liquid is allowed to stand 2 or 3 hrs., filtered, and the precipitate washed free from chlorides with hot water. The dry precipitate is ignited in a weighed platinum crucible. The ignition is conducted slowly at first, and finally over a blast for about 15 mins.—placing the lid on the crucible for the last 5 mins. The crucible is weighed rapidly when cool.

#### *Determination of magnesia.*

1 to 2 grm. of sodium ammonium phosphate are added to the first filtrate from the ammonium oxalate precipitate, and the mixture boiled whilst covered with a clock-glass. 10 cc. of concentrated ammonia are added, and the mixture allowed to stand for at least 3 hrs. The mixture is stirred vigorously when cold, filtered, and the precipitate washed once with cold water, rejecting the filtrate. A hole is made in the filter-paper, the precipitate washed into the beaker from which it has been filtered, and the ammonium magnesium phosphate redissolved in nitric acid. The solution is heated to boiling, 1–2 grm. of sodium ammonium phosphate and 10–15 cc. of concentrated ammonia are added, and the mixture allowed to stand for 2 hrs. The cold mixture is thoroughly stirred, filtered through a weighed Gooch crucible, and the precipitate washed free from soluble phosphates with cold ammonia solution (1 : 8). The dry precipitate is ignited, cooled, and weighed as magnesium pyrophosphate.

#### *Determination of alkalis.*

About 0.5 grm. of finely powdered dry clay are intimately mixed with about 0.5 grm. of ammonium chloride and 3 grm. of calcium carbonate in an agate mortar, and transferred to a platinum crucible, cleaning out the mortar with a further gram of calcium carbonate. The crucible and contents are heated over a small Bunsen flame for about 15 mins. The lid is kept partly on the crucible whilst the ammonium chloride is being volatilised, then placed in position, and the crucible and contents heated for 1 hr. with the lower third of the crucible at a dull red heat (not sufficiently high to melt the mass). The crucible is allowed to cool slowly, the cake is transferred to a porcelain dish, and the crucible is thoroughly washed with hot distilled water. After standing 2 or 3 mins., the cake in the dish is gently crushed to powder with an agate pestle. The mass is digested with 80 cc. of water for 30 mins., filtered, and the precipitate washed with hot



water 8 or 9 times; the filtrate should occupy 100—150 cc. The precipitate is rejected. 10 cc. of ammonium carbonate (see later) are added to precipitate the lime from the boiling hot filtrate; the liquid is filtered and the filtrate retained. The precipitate is washed into the same beaker from which it was filtered, and dissolved in hydrochloric acid (about 5 cc.). The solution is boiled and a slight excess of ammonia and ammonium carbonate added, and the mixture is filtered into the same beaker as before. The solution is evaporated to dryness in a platinum basin, and the dry residue ignited by gradually raising the temperature to faint redness in order to volatilise the ammonium salts. 3 cc. of ammonium carbonate are added to the residue in order to precipitate the last traces of lime, the liquid covered with a clock-glass, and allowed to stand over-night. The mixture is filtered into a small platinum dish; the precipitate is washed with a solution of ammonium carbonate, and the filtrate is again evaporated to dryness on a water-bath. As the liquid tends to spurt during the early stages of the evaporation, the basin is covered with a clock-glass and any liquid adhering to the glass is washed back into the basin. When dry the contents of the dish are moistened with a small amount of concentrated hydrochloric acid and again evaporated. The residue is ignited at a dull red heat, cooled, and weighed. The platinum dish is re-heated and weighed. The difference in weight represents the alkali chlorides. The residue containing the alkali chlorides is washed with hot water into a small porcelain dish, and evaporated almost to dryness with perchloric acid, 10 cc. of water added, and again evaporated almost to dryness. Six times the weight of the mixed chlorides represents the number of cc. of 30% perchloric acid of Sp. Gr. 1.20 to be used in the test. The residue is treated with a mixture of 97 volumes of absolute alcohol, 3 volumes of water, and 0.25 volumes of perchloric acid. The mixture is filtered at once through a weighed Gooch crucible previously heated to  $120^{\circ}$ , and the residue washed with the alcohol mixture indicated above. The crucible and contents are then dried at  $120^{\circ}$  for about 45 mins., and weighed. The potassium perchlorate weighed is calculated to potassium chloride, which is subtracted from the weight of the mixed chlorides to obtain sodium chloride; the corresponding potash and soda contents are then calculated.

NOTES.—(a) The volume of the liquid should be kept as low as possible.

(b) The first precipitate should be well washed, particularly if the amount of alkali is large.

- (c) The first ignition must not be above  $700^{\circ}$ , and subsequent ignitions should not exceed a faint red heat, or alkalies will be lost by volatilisation.
- (d) The last washing should be made with ammonium carbonate solution, or the result will be too high.
- (e) Only porcelain or platinum, not glass, vessels should be used for the evaporation

*Ammonium carbonate solution.*

100 grm. of ammonium carbonate are dissolved in 100 cc. of concentrated ammonia (0.880), and the solution made up to 500 cc. with water.

### POROSITY TEST.

The porosity of a brick is to some extent a measure of the "density" and texture of the brick. The test is conducted as follows:—A representative piece of the firebrick or refractory material to be tested is cut into rough cubes, about 2 in. side. The sample is dried at  $110^{\circ}$  for about 2 hrs. and weighed. It is then soaked in water under reduced pressure for some hours, preferably overnight—a vacuum dessicator is very suitable for this purpose. The piece is then weighed while suspended in water as in ordinary specific gravity determinations; the surface water is wiped off, and the piece is again weighed. The porosity, or the volume of the pores expressed as a percentage volume of the whole piece, is 100 times the quotient obtained by dividing the difference between weights of the piece soaked and dried by the apparent loss in weight which the soaked piece suffers when weighed in air and then weighed suspended in water. Duplicates should agree within 0.2%. With very dense or close textured material, it is necessary to soak the sample for 2 or 3 days, otherwise the air bubbles in the centre of the piece are not displaced by water. The elimination of the air is also assisted by reducing the pressure inside the dessicator. The specific gravity of the sample may also be calculated from the above data, since the apparent specific gravity of the lump is the quotient obtained by dividing the weight of the dry sample by the apparent loss in weight which the soaked piece suffers when weighed in air and then suspended in water. The specific gravity of the solid material (powder) is the quotient obtained by dividing the weight of the dry test piece by the apparent loss of weight which the dry piece suffers when weighed in air and then suspended in water—after soaking.

The apparent specific gravity of an average firebrick in lump



usually varies from 1.5 to 1.9, and the powdered brick has a specific gravity ranging between 2.3-2.6; the porosity varies from 20 to 35%.

## DETERMINATION OF THE REFRACTORINESS OF FIREBRICKS, FIRECLAYS, Etc.

A representative piece of the material is chipped or shaped into the form of a cone about  $1\frac{1}{2}$  inch in height. The cone is cemented to the centre of a refractory disc, about 2 inches in diameter, by means of a mixture of ground bauxite and fireclay, and Seger cones are cemented around the test-piece. The cones are chosen in the order of increasing temperatures according to the material being tested. The cones should be sloped slightly in the outward direction, so that they will not fall on to the test-piece when they melt. The disc is placed on the supports of the lifting-table of a Hirsch or similar electric furnace. The current is started running with a power of 2 or 3 kilowatts. The temperature of the furnace must be increased regularly about  $50^{\circ}$  per 5 mins., until the cone begins to melt. If the increase in temperature is too rapid the voltage must be decreased by means of an adjustable transformer or resistance. The power taken at high temperature varies from 7-10 kilowatts, the voltage has to be varied according as the resistance of the furnace is high or low. The cones should melt at an interval of 5 mins.; if two or more cones squat at nearly the same temperature, the increase in temperature is too rapid, and this makes the softening point of the test-piece appear too high. The temperature at which the test-piece bends over, squats, or shows signs of fusion is taken as the softening point. At this point the current is switched off, the support lowered, and the disc containing test-piece and cones plunged into cold water. This prevents the disc, etc., breaking up on cooling. The softening point of the test-piece is deduced from the cone which bent down last. The squatting temperature of a Seger cone corresponds with the temperature at which the cone bends over so that the tip is level with the base. The selection of the right cones for an unknown sample is made by successive approximation. For example, cones 20, 26, 30, 32 and 35 would be placed on the refractory disc with the clay to be tested. If cones 20 and 26 are down, and 30 to 35 are standing when the clay squats, it would be inferred that the clay squats between cones 26 and 30. In a second trial, therefore, cones 26 to 30 would be placed on the disc with the clay. The softening point of the test-piece often comes between the squatting temperature of the two cones, since the one has gone

down completely and the other one just commenced to bend. The bending temperatures of Seger cones are given in the accompanying table. The comparison of the squatting temperature of refractories with a standard cone is better than expressing the results in terms of a pyrometer reading. The use of the term squatting or softening temperature is also preferable to the term melting point, since refractory materials rarely have a sharp melting point.

#### APPROXIMATE SQUATTING TEMPERATURES OF SEGER CONES.

| Cone |      |      | Cone |      |      | Cone |      |      |
|------|------|------|------|------|------|------|------|------|
| No.  | °C.  | °F.  | No.  | °C.  | °F.  | No.  | °C.  | °F.  |
| 022  | 600  | 1112 | 02a  | 1060 | 1940 | 19   | 1520 | 2768 |
| 021  | 650  | 1202 | 01a  | 1080 | 1976 | 20   | 1530 | 2786 |
| 020  | 670  | 1238 | 1a   | 1100 | 2012 | 26   | 1580 | 2876 |
| 019  | 690  | 1274 | 2a   | 1120 | 2048 | 27   | 1610 | 2930 |
| 018  | 710  | 1310 | 3a   | 1140 | 2084 | 28   | 1630 | 2966 |
| 017  | 730  | 1346 | 4a   | 1160 | 2120 | 29   | 1650 | 3002 |
| 016  | 750  | 1382 | 5a   | 1180 | 2156 | 30   | 1670 | 3038 |
| 015a | 790  | 1454 | 6a   | 1200 | 2192 | 31   | 1690 | 3074 |
| 014a | 815  | 1499 | 7    | 1230 | 2246 | 32   | 1710 | 3110 |
| 013a | 835  | 1535 | 8    | 1250 | 2282 | 33   | 1730 | 3146 |
| 012a | 855  | 1571 | 9    | 1280 | 2336 | 34   | 1750 | 3182 |
| 011a | 880  | 1616 | 10   | 1300 | 2372 | 35   | 1770 | 3218 |
| 010a | 900  | 1652 | 11   | 1320 | 2408 | 36   | 1790 | 3254 |
| 09a  | 920  | 1688 | 12   | 1350 | 2462 | 37   | 1825 | 3317 |
| 08a  | 940  | 1724 | 13   | 1380 | 2516 | 38   | 1850 | 3362 |
| 07a  | 960  | 1760 | 14   | 1410 | 2570 | 39   | 1880 | 3416 |
| 06a  | 980  | 1796 | 15   | 1435 | 2615 | 40   | 1920 | 3488 |
| 05a  | 1000 | 1832 | 16   | 1460 | 2660 | 41   | 1960 | 3560 |
| 04a  | 1020 | 1868 | 17   | 1480 | 2696 | 42   | 2000 | 3632 |
| 03a  | 1040 | 1904 | 18   | 1500 | 2732 |      |      |      |

#### DETERMINATION OF THE AFTER-CONTRACTION OR AFTER-EXPANSION OF REFRACTORY MATERIALS.

The so-called test is designed to find the after-contraction or after-expansion of a firebrick, *i.e.* the change in size which the brick is likely to undergo when in use at high temperature. The temperature used for testing is equivalent to cone 14 (1,410°C., 2,570°F.) for all bricks. In making the test a rectangular piece of the material—about 3 ins. in length and 1 to 2 ins. in width and depth—is cut from the sample. The opposite ends are ground parallel on an emery or carborundum wheel, and the length measured by means of a vernier gauge reading to 0.005 cm. The piece is then fired until the proper

cone squats, and is maintained at this temperature for 2 hrs. After the cone has squatted a pyrometer is required to check the fluctuations of temperature. A gas furnace worked with an air-blast is used, with an oxidising atmosphere. When cold the length of the test-piece is again measured and the alteration in size calculated. The test is best done in duplicate, one piece from the outside and one from the inside of the sample. The maximum contraction or expansion allowed by the Gas Engineers' Specification is: *Silica bricks*, 0.50%; *retort material*, 1.0%; *firebricks, grade I*, 0.75%; and *firebricks, grade II*, 1.15%. The testing temperature with all materials corresponds with cone 14. A number of users consider these tests are not sufficiently severe, and that the testing temperature should be raised.

*Additions by Editor.*

### Standard American Methods.

#### STANDARD TEST FOR POROSITY AND PERMANENT VOLUME CHANGES IN REFRACTORY MATERIALS.

(American Society for Testing Materials, 1920.)

The sample for this test should consist of at least seven standard-size bricks, and test-pieces are cut from these, so as to remove the original surface of the bricks. The test-pieces should measure  $2\frac{1}{2}$  by  $2\frac{1}{2}$  by  $1\frac{1}{4}$  in., and should be 35 in number, 5 for each of the seven heat treatments. Adhering dust is washed or brushed from the pieces, which are then numbered by means of a refractory stain, dried at 110°C. and weighed to within 0.1 g., giving the dry weight (D). The test-pieces are placed in kerosene of known density ( $\delta$ ) under 24 in. of vacuum for 4 hrs. at 25°C., and allowed to cool to room temperature while immersed. When cool each test-piece is weighed suspended in kerosene at 25°C. to determine its suspended weight (S), and is then wiped with a kerosene-moistened towel, and weighed in air to give the saturated weight (W).

The true specific gravity (T) is obtained by crushing a portion of the dried test-piece to pass through a 120-mesh sieve, and determining the displacement at 25°C. under 24 in.

of vacuum of a 20 grm. sample of the powder in a 50 cc. straight-walled pyknometer under kerosene, correcting for the density of the kerosene.

The required data are given by the following formulæ :

$$\text{Exterior volume in cc. (V)} = \frac{W-S}{\delta} \quad - \quad - \quad - \quad (1)$$

$$\text{Actual volume of open pores in cc. (V}_1\text{)} = \frac{W-D}{\delta} \quad - \quad - \quad (2)$$

$$\text{Apparent specific gravity (T}_1\text{)} = \frac{D}{D-S} \delta \quad - \quad - \quad - \quad (3)$$

$$\text{Volume of sealed pores in cc. (V}_2\text{)} = \frac{D-S}{\delta} - \frac{D}{T} \quad - \quad - \quad (4)$$

The 35 test-pieces are now thoroughly dried at 110°C., placed in a kiln, and heated as rapidly as is consistent with even heat distribution to 1200°C. Five test-pieces are withdrawn, and the kiln temperature raised at the rate of 30° per hour to 1500°C., five test-pieces being withdrawn at each 50° interval from 1200°C to 1500°C. If a sufficient number of brands is under examination to warrant it, separate burns to each temperature are made, and the kiln is sealed and allowed to cool by radiation. If this cannot be carried out, the five test-pieces from each temperature increment should be covered with hot sand immediately on being drawn, or placed in a supplementary kiln and kept at 500°C. until all drawings are completed. This kiln is then sealed and allowed to cool by radiation.

When cold, each test-piece is subjected to the series of tests above, to determine its dry weight, suspended weight, saturated weight, and true specific gravity. From these are calculated the *exterior volume, actual volume of open pores, apparent specific gravity, and volume of sealed pores.*

The *volume shrinkage* is obtained by subtracting the external volumes (*i.e.* values of  $\frac{W-S}{\delta}$  before and after the heat treatment. To show progressive changes in the several volumes, all volumes are referred back to the original exterior volume of the test-piece as 100, and following this the results are given as the average of the five test-pieces for each heat treatment.

## STANDARD TEST FOR SOFTENING POINT (REFRACTORINESS) OF FIREBRICK, Etc.

(American Society for Testing Materials, 1920.)

The softening point of fireclay brick, etc., is determined by comparison of test cones with standard Orton pyrometric cones in a suitable furnace.

A sample of approximately 1 kg. is taken by chipping off roughly equal pieces from corners of the brick. The sample is crushed so that the pieces have a maximum diameter of 6 mm., and is then quartered twice to reduce to approximately 250 gm. Metallic iron is removed from the sample by means of a magnet, and the sample is then ground in an agate or porcelain mortar to pass a standard 60-mesh sieve. During the grinding the finer particles are frequently removed by means of the sieve, to prevent their excessive reduction in size. The fine sample is then thoroughly mixed, and after addition of sufficient dextrine or glue and water, is formed into test cones in a metal mould, in the shape of a tetrahedron, measuring 5 mm. at the side of the base, and 25 mm. high. The test cones are dried, and then baked at a temperature not exceeding 1300°C. to allow firm handling.

The test cones are mounted on plaques of refractory material which will not affect the fusibility of the cones. (A mixture of equal parts of a good grade of china clay and fused alumina which will pass a 100-mesh sieve is satisfactory.) The cones are mounted with the base embedded approximately 1 mm. in the plaque, and one face inclined at 75° with the horizontal. These cones are alternated with the Orton cones, so that Orton cones of successive numbers are opposite each other. The heating is carried out in a suitable furnace at a rate between 10°C. and 15°C. per minute after Orton cone No. 1 has softened. The furnace should have a neutral or oxidising atmosphere, and the flame should not strike the cones or the plaque. The softening point of the cone is indicated by the top bending over, and is reported in terms of Orton cones, being that cone which most nearly corresponds in time of softening with the test cone. If the test cone softens later than one Orton cone, and earlier than the next, both cones are reported, *e.g.*, cone No. 31-32.

Bloating, squatting or unequal fusion of small particles should be reported, also any peculiarity, such as if the test cone commences to bend at an early Orton cone, but is not properly softened until a considerably later one.

# ANALYSIS OF PORTLAND CEMENT.

A. GROUNDS, B.Sc. Tech., A.I.C., Assoc. M.I.Min.E.

## (1) Loss on ignition,

1.0 grm. of the sample is heated gently in a platinum crucible for 5 mins. and then at  $800^{\circ}\text{C}$ . (between a bright red heat and a dull orange) for 1 hour. After cooling and weighing, the heating is continued until no further loss in weight occurs. The loss on ignition is due to the expulsion of water and carbon dioxide; the carbonate may be estimated by treating 2—5 grms. of the powdered cement with hydrochloric acid, and absorbing the carbon dioxide (after passage through a silver-sulphate tube and a wash-bottle containing strong sulphuric acid) in a 40% solution of caustic potash, contained in a weighed potash bulb.

## (2) Silica and insoluble matter.

(a). 0.5 grm. of cement is well stirred with 15 cc. water in a porcelain basin, 25 cc. of hydrochloric acid (Sp. Gr. 1.2) added, and boiled down carefully to about 10 cc. The basin is covered with a clock-glass, and the contents evaporated to dryness and baked for one hour at  $180^{\circ}\text{C}$ . When cool, the residue is treated with 25 cc. concentrated hydrochloric acid, warmed gently, and the clock-glass washed with hot distilled water. The precipitate is filtered off, washed, dried, ignited, and weighed, when the weight gives the silica and insoluble matter.

(b). (a) is repeated, but when filtering from silica and insoluble matter the washing is carried out by decantation, and any precipitate on the filter paper is washed back into the dish. The silica is dissolved out by boiling for half an hour with 25 cc. of a saturated solution of sodium carbonate. The insoluble matter is then rapidly filtered off, washed free from carbonate with boiling water, dried, ignited, and weighed.

The difference between (a) and (b) gives the amount of soluble silica, whilst (b) gives the insoluble matter.

## (3) Alumina.

The filtrate from 2 (a) is oxidised with bromine in presence of ammonia, excess being expelled by boiling. The precipitate is filtered off, dissolved in hydrochloric acid, and reprecipitated with ammonia, to ensure that the precipitate is free from calcium. The precipitate is dried, ignited, and weighed as aluminium and iron oxides.

The alumina is obtained by subtracting from this figure the ferric oxide, determined as in (4).



**(4) Iron.**

This is determined in the filtrate and washings from 2 (b), after precipitation of sulphates as barium sulphate, by titration with standard titanous chloride or titanous sulphate.

**(5) Lime.**

Calcium is precipitated as oxalate in the filtrate and washings from (3), and is weighed as calcium oxide.

**(6) Magnesia.**

The filtrate and washings from (5) are evaporated almost to dryness, 25 cc. of nitric acid (Sp. Gr. 1.5) added, and the liquid warmed gently to remove all traces of ammonium salts. The residue is treated with water and a few drops of hydrochloric acid, and 3 cc. of a 10% solution of ammonium chloride added. Excess ammonia is added together with a few drops of ammonium oxalate, the solution boiled, and any precipitate filtered off and added to the lime precipitate. Magnesium is then estimated in the filtrate by means of sodium phosphate.

**(7) Sulphur trioxide.**

This is estimated in the filtrate and washings from 2 (b) by precipitation as barium sulphate.

**(8) Sulphur (as sulphide).**

0.5 gm. of the cement is dissolved in a small amount of water and 25 cc. of concentrated nitric acid. The total sulphate is then determined, and by subtracting the sulphate found in (7) the amount of sulphate corresponding to the sulphide present.

**(9) Alkalies and Loss.**

This is taken as the difference between 100% and the sum of the results obtained above.

If the percentage of alkalies is required for any special purpose, it must be determined by, *e.g.*, the Laurence Smith process.

### **Rapid Determination of Lime in Portland Cement without the separation of alumina, ferric oxide, silica, &c.**

0.5 gm. of the sample is mixed with 30 cc. of distilled water, 10—15 cc. concentrated hydrochloric acid added, and the mixture heated for about 10 minutes until all soluble matter is dissolved. The solution is then brought to the boil, and sufficient ammonia added to produce a slight permanent

precipitate. The solution is boiled again, and 10 cc. of a 10% solution of oxalic acid added. When the hydroxides of iron and alumina have dissolved and only a slight precipitate of calcium oxalate remains, 200 cc. of boiling water and 25 cc. of a saturated solution of ammonium oxalate added, and the mixture boiled for 5 mins. The precipitate is allowed to settle, and is filtered, and then washed ten times with small quantities of hot water, the paper being allowed to drain thoroughly each time. The precipitate is washed into a beaker with hot water, 5—10 cc. of dilute sulphuric acid added, the mixture heated to 80°C., and the liquid titrated with standard potassium permanganate.

5.64 grm. of potassium permanganate made up to a litre gives a solution of which 1 cc. = 0.005 grm. CaO.

## British Standard Specifications for Portland Cement.

(May, 1915).

The limits allowed are as follows:—

(i) The percentage of insoluble residue shall not exceed 1.50%.

(ii) The percentage of magnesia shall not exceed 3.00%.

(iii) The percentage of total sulphur shall not exceed 2.75% SO<sub>3</sub>.

(iv) The percentage of total loss on ignition shall not exceed 3.00%.

(v) The proportion of lime to silica and alumina, when calculated (in chemical equivalents) by the formula

$$\frac{\text{CaO}}{\text{SiO}_2 + \text{Al}_2\text{O}_3}$$

shall not exceed 2.85 nor be less than 2.0; this ratio is known as the hydraulic modulus.

Example. In a cement containing 63.28% lime, 21.6% silica, and 8.16% alumina, the proportion of lime to silica and alumina is as follows:—

$$\frac{\text{CaO}}{\text{SiO}_2 + \text{Al}_2\text{O}_3} = \frac{63.28/56}{21.6/60 + 8.16/102} = 2.5\%.$$

(vi) Residue on a 180<sup>2</sup> sieve must not exceed 12%.

(vii) Residue on a 76<sup>2</sup> sieve must not exceed 1%.

(viii) Specific Gravity of the cement shall be not less than 3.10.



# Standard Specifications and Tests for Cement as approved by the American Society for Testing Materials, 1921.

## Standard Specifications.

The limits allowed are as follows :

- (1) Loss on ignition shall not exceed 4.00%.
- (2) Insoluble residue shall not exceed 0.85%.
- (3) Sulphuric anhydride shall not exceed 2.00%  $\text{SO}_3$ .
- (4) Magnesia shall not exceed 5.00%  $\text{MgO}$ .
- (5) The specific gravity shall not be less than 3.10 (3.07 for white Portland cement).
- (6) The residue on a standard No. 200 sieve shall not exceed 22% by weight.

(7) A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

(8) The cement shall not develop initial set in less than 45 mins. when the Vicat needle is used, or 60 mins. when the Gillmore needle is used. Final set shall be attained within 10 hrs.

(9) The average tensile strength of not less than 3 standard mortar briquettes composed of one part cement and three parts standard sand shall not be less than 200 lbs. per sq. in. after standing one day in moist air and then six days in water, or less than 300 lbs. per sq. in. after standing one day in moist air followed by 27 days in water.

(10) The average strength of standard mortar at 28 days shall be higher than the strength at 7 days.

## Analysis. (Summary of A.S.T.M. methods, 1921.)

### (1) *Loss on ignition.*

1 grm. of cement is heated in a weighed covered platinum crucible, either set in an asbestos board at a full red heat for 15 mins. over an inclined blow-pipe flame, or in a muffle furnace at  $900^{\circ}$  to  $1000^{\circ}\text{C}$ . for 15 mins. In either case the loss in weight is checked by a second heating for 5 mins.

### (2) *Insoluble residue.*

1 grm. of cement is warmed with 10 cc. of water and 5 cc. of concentrated hydrochloric acid until effervescence ceases, diluted to 50 cc., and digested until decomposition of the cement is complete. The residue is filtered, washed, and, together with the filter-paper, digested with 30 cc. of a 5% solution of sodium carbonate for 15 mins. The remaining residue is filtered, washed with cold water, then with a few drops of hot hydrochloric acid (1:9), and finally with hot water. The filter-paper and contents are ignited at red heat, and weighed as the insoluble residue.

### (3) *Sulphuric anhydride.*

This is estimated in the acid filtrate and washings from the determination of insoluble residue by precipitation as barium sulphate.

### (4) *Magnesia.*

0.5 gm. of cement is mixed with 10 cc. of water in a porcelain basin, 10 cc. of concentrated hydrochloric acid added, and the liquid evaporated to dryness and baked for 1 hr. at 150° to 200°C. The residue is digested for 10 mins. with 20 cc. of hydrochloric acid (1:1), and the silica filtered off and thoroughly washed. To the filtrate are added 5 cc. of concentrated hydrochloric acid and sufficient bromine water to precipitate any manganese present, then iron and aluminium are precipitated by means of ammonium hydroxide.

The iron and aluminium hydroxides are filtered off (filtrate A), and are dissolved in hydrochloric acid, re-precipitated with ammonium hydroxide and bromine water, and again filtered off. This filtrate is combined with filtrate A, the mixture brought to the boil, 25 cc. of a boiling saturated solution of ammonium oxalate added, and the boiling continued until the calcium oxalate is granular in form. After allowing to stand for 1 hr., the calcium oxalate is filtered off (filtrate B), ignited, redissolved in hydrochloric acid, and re-precipitated by means of ammonium hydroxide and ammonium oxalate. The filtrate from this precipitate is combined with filtrate B, acidified with hydrochloric acid, concentrated to about 150 cc., made slightly alkaline with ammonium hydroxide, boiled, and filtered if necessary. The filtrate is cooled, 10 cc. of a saturated solution of sodium-ammonium-hydrogen phosphate added with stirring, and when the magnesium is precipitated as ammonium-magnesium orthophosphate, excess of ammonia is added, and the solution allowed to stand for several hours. The magnesium precipitate is filtered off, washed with water containing 2.5% of ammonia, then is re-dissolved, re-precipitated, filtered, and washed as previously. The precipitate is ignited to constant weight over a Méker burner, and the final weight of magnesium pyrophosphate, multiplied by 72.5, gives the % MgO present.

### (5) *Specific gravity.*

This is determined on 64 gm. of cement by means of a Le Chatelier apparatus, as standardized by the Bureau of Standards.

### (6) *Fineness.*

This is determined on 50 gm. of cement, using a No. 200 sieve, as standardized by the Bureau of Standards.

For description of physical tests and apparatus, see "A.S.T.M. Standards," 1921.

# Percentage Composition of Various Portland Cements.

| Brand of cement.               | Insol.   |      |      |      |       |      |      |      |      |      | Loss on<br>ignition. | S as<br>sulphide.       | Alkalies<br>and loss. | Hydraulic<br>modulus. | Observer. |
|--------------------------------|--|------|------|------|-------|------|------|------|------|------|----------------------|-------------------------|-----------------------|-----------------------|-----------|
|                                | CaO Al <sub>2</sub> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub> MgO SiO <sub>2</sub> residue SO <sub>3</sub> |      |      |      |       |      |      |      |      |      |                      |                         |                       |                       |           |
| British, Rotary kiln, No. 1 .. | 62.67  | 6.66 | 3.22 | 0.98 | 20.76 | 0.80 | 1.81 | 1.45 | 0.39 | 1.25 | 2.72                 | Grounds                 |                       |                       |           |
| British, Rotary kiln, No. 2 .. | 62.95  | 6.35 | 3.95 | 1.63 | 21.09 | 0.51 | 1.45 | 1.18 | 0.32 | 0.57 | 2.71                 |                         |                       |                       |           |
| British, Ship Canal P.C. Co.   | 62.05  | 6.72 | 2.93 | 2.26 | 21.35 | 0.58 | 1.31 | 1.25 | 0.21 | 1.34 | 2.63                 |                         |                       |                       |           |
| British, Wiggins' P.C. ..      | 62.47  | 8.15 | 2.30 | 1.55 | 20.18 | 0.67 | 1.81 | 2.34 | 0.00 | 0.53 | 2.70                 | Miskin                  |                       |                       |           |
| Russian .. .. .                | 63.40  | 5.01 | 2.30 | 0.92 | 23.97 | 1.04 | 0.81 | 1.85 | 0.38 | 0.32 | 2.52                 | Grounds                 |                       |                       |           |
| Chicago, A.A. .. ..            | 61.95  | 7.67 | 2.61 | 2.82 | 20.05 | 0.71 | 1.68 | 0.29 | 0.04 | 2.18 | 2.70                 | "                       |                       |                       |           |
| Atlas (U.S.A.) .. ..           | 60.89  | 8.03 | 2.94 | 2.05 | 22.01 | 0.42 | 1.07 | 0.03 | 0.62 | 1.94 | 2.64                 | "                       |                       |                       |           |
| *Sandusky (U.S.A.) ..          | 62.38  | 6.16 | 2.90 | 1.21 | 23.08 | -    | 1.66 | -    | -    | 3.61 | 2.50                 | Booth, Garrett & Blair. |                       |                       |           |
| Condlot (French) ..            | 62.80  | 8.50 | 3.10 | 0.45 | 22.30 | -    | 0.70 | -    | -    | 2.15 | 2.46                 | Condlot.                |                       |                       |           |
| Boulogne (French) ..           | 64.62  | 7.00 | 2.50 | 1.04 | 22.30 | -    | 0.75 | -    | -    | 1.81 | 2.62                 | "                       |                       |                       |           |
| Dyckerhoff .. .. .             | 63.06  | 7.15 | 3.69 | 2.33 | 20.64 | -    | 1.39 | -    | -    | 1.74 | 2.72                 | Booth, Garrett & Blair. |                       |                       |           |
| White Label, Alsen. ..         | 64.30  | 7.28 | 3.88 | 1.76 | 20.48 | -    | 2.46 | -    | -    | 1.84 | 2.78                 | "                       |                       |                       |           |

\* From "Mineral Industry of the United States," Vol. vi

## Analyses of American Portland Cements. (Richard K. Meade).

|                          | SiO <sub>2</sub> | Fe <sub>2</sub> O <sub>3</sub> | Al <sub>2</sub> O <sub>3</sub> | CaO   | MgO  | Alkalies | So <sub>2</sub> | Loss |
|--------------------------|------------------|--------------------------------|--------------------------------|-------|------|----------|-----------------|------|
| Nazareth, Pa. ....       | 19.92            | 2.28                           | 7.52                           | 62.48 | 3.19 | 1.18     | 1.51            | 1.46 |
| Nazareth, Pa. ....       | 21.14            | 2.30                           | 6.94                           | 63.24 | 3.26 | 0.87     | 1.12            | 1.24 |
| Beth, Pa. ....           | 19.64            | 2.80                           | 7.52                           | 62.31 | 3.04 | —        | 1.60            | 1.48 |
| Alpha, N. J. ....        | 21.82            | 2.51                           | 8.03                           | 62.19 | 2.71 | —        | 1.02            | 1.05 |
| Northampton, Pa. ....    | 21.94            | 2.37                           | 6.87                           | 60.25 | 2.78 | 1.48     | 1.38            | 3.55 |
| Coplay, Pa. ....         | 22.26            | 2.10                           | 5.36                           | 63.32 | 3.81 | —        | 0.89            | 1.24 |
| Omrod, Pa. ....          | 22.20            | 2.27                           | 6.69                           | 62.61 | 3.00 | 0.93     | 1.32            | 1.56 |
| Martin's Creek, Pa. .... | 20.32            | 2.50                           | 7.12                           | 62.94 | 3.38 | —        | 1.45            | 1.25 |
| Reading, Pa. ....        | 24.16            | 1.45                           | 5.10                           | 62.95 | 3.12 | 0.71     | 1.35            | 1.40 |
| Bay City, Mich. ....     | 20.72            | 2.85                           | 7.17                           | 62.64 | 1.97 | 0.60     | 1.42            | 2.58 |
| Wellston, O. ....        | 21.84            | 5.05                           | 6.77                           | 62.66 | 0.80 | —        | 1.24            | —    |
| Chanute, Kan. ....       | 20.74            | 3.72                           | 7.06                           | 62.76 | 1.78 | 0.64     | 1.12            | 1.40 |
| Ada, Okla. ....          | 12.28            | 3.20                           | 6.36                           | 59.66 | 3.11 | 1.05     | 1.40            | 2.82 |
| Alsen, N. Y. ....        | 23.94            | 3.20                           | 5.62                           | 62.32 | 1.77 | —        | 0.90            | 1.68 |
| Fordwick, Va. ....       | 21.31            | 2.81                           | 6.54                           | 63.01 | 2.71 | —        | 1.42            | 2.01 |
| Davenport, Cal. ....     | 25.38            | 1.20                           | 3.34                           | 62.96 | 1.20 | —        | 0.35            | 4.58 |
| Cement, Cal. ....        | 22.34            | 3.30                           | 7.00                           | 60.72 | 1.30 | —        | 1.05            | 2.54 |
| St. Louis, Mo. ....      | 23.12            | 2.49                           | 6.18                           | 63.47 | 0.88 | —        | 1.34            | 1.81 |
| Demopolis, Ala. ....     | 19.36            | 4.10                           | 9.18                           | 63.20 | 1.16 | —        | 1.18            | 1.12 |
| Sandusky, O. ....        | 21.93            | 2.35                           | 5.99                           | 62.92 | 1.10 | 0.90     | 1.55            | 2.92 |
| Chicago, Ill. ....       | 22.41            | 2.51                           | 8.12                           | 62.01 | 1.68 | —        | 1.40            | 1.02 |
| Chicago, Ill. ....       | 23.06            | 2.88                           | 6.12                           | 62.10 | 1.88 | 0.94     | 1.57            | —    |

## ACID AND ALKALI MANUFACTURE.

## Sulphuric Acid.

*Valuation of Sulphur.* 50 grm. of the powdered sulphur are digested with 200 cc. of carbon disulphide (purified by distilling over mercury and mercury oxide), and the Specific Gravity of the solution determined. The % sulphur by volume found from the following table is multiplied by 4 to obtain the sulphur content of the sample. The ash is determined by igniting 10 grm. in a tared porcelain dish.

**Specific Gravity of Solutions of Sulphur in Carbon Disulphide at 15° C. (Macagno).**

| Sp. Gr. | % S. | Sp. Gr. | % S. | Sp. Gr. | % S. | Sp. Gr. | % S. |
|---------|------|---------|------|---------|------|---------|------|
| 1.271   | 0    | 1.301   | 7.2  | 1.331   | 14.5 | 1.361   | 22.1 |
| 72      | 0.2  | 02      | 7.5  | 32      | 14.7 | 62      | 22.3 |
| 73      | 0.4  | 03      | 7.8  | 33      | 15.0 | 63      | 22.7 |
| 74      | 0.6  | 04      | 8.0  | 34      | 15.2 | 64      | 23.0 |
| 75      | 0.9  | 05      | 8.2  | 35      | 15.4 | 65      | 23.2 |
| 76      | 1.2  | 06      | 8.5  | 36      | 15.6 | 66      | 23.6 |
| 77      | 1.4  | 07      | 8.7  | 37      | 15.9 | 67      | 24.0 |
| 78      | 1.6  | 08      | 8.9  | 38      | 16.1 | 68      | 24.3 |
| 79      | 1.9  | 09      | 9.2  | 39      | 16.4 | 69      | 24.8 |
| 80      | 2.1  | 10      | 9.4  | 40      | 16.6 | 70      | 25.1 |
| 81      | 2.4  | 11      | 9.7  | 41      | 16.9 | 71      | 25.6 |
| 82      | 2.6  | 12      | 9.9  | 42      | 17.1 | 72      | 26.0 |
| 83      | 2.9  | 13      | 10.2 | 43      | 17.4 | 73      | 26.5 |
| 84      | 3.1  | 14      | 10.4 | 44      | 17.6 | 74      | 26.9 |
| 85      | 3.4  | 15      | 10.6 | 45      | 17.9 | 75      | 27.4 |
| 86      | 3.6  | 16      | 10.9 | 46      | 18.1 | 76      | 28.1 |
| 87      | 3.9  | 17      | 11.1 | 47      | 18.4 | 77      | 28.5 |
| 88      | 4.1  | 18      | 11.3 | 48      | 18.6 | 78      | 29.0 |
| 89      | 4.4  | 19      | 11.6 | 49      | 18.9 | 79      | 29.7 |
| 90      | 4.6  | 20      | 11.8 | 50      | 19.0 | 80      | 30.2 |
| 91      | 4.8  | 21      | 12.1 | 51      | 19.3 | 81      | 30.8 |
| 92      | 5.1  | 22      | 12.3 | 52      | 19.6 | 82      | 31.4 |
| 93      | 5.3  | 23      | 12.6 | 53      | 19.9 | 83      | 31.9 |
| 94      | 5.6  | 24      | 12.8 | 54      | 20.1 | 84      | 32.6 |
| 95      | 5.8  | 25      | 13.1 | 55      | 20.4 | 85      | 33.2 |
| 96      | 6.0  | 26      | 13.3 | 56      | 20.6 | 86      | 33.8 |
| 97      | 6.3  | 27      | 13.5 | 57      | 21.0 | 87      | 34.5 |
| 98      | 6.5  | 28      | 13.8 | 58      | 21.2 | 88      | 35.2 |
| 99      | 6.7  | 29      | 14.0 | 59      | 21.5 | 89      | 36.1 |
| 1.300   | 7.0  | 30      | 14.2 | 60      | 21.8 | 90      | 36.7 |

### *Valuation of Pyrites.*

Moisture is determined at  $105^{\circ}\text{C}$ . in 5 grm. of the sample.

0.5 grm. of the finely powdered sample is treated with 10 cc. of a mixture of 1 volume of concentrated hydrochloric acid and 3 volumes of concentrated nitric acid. After evaporating on the water-bath, the residue is treated with hydrochloric acid, again evaporated, and extracted with dilute hydrochloric acid and then with hot water. Ammonia is added to the warm filtrate to precipitate iron. The filtrate is acidified with hydrochloric acid, evaporated to 200 cc., and a moderate excess of a boiling solution of barium chloride, containing hydrochloric acid, added to the warm solution. After digesting on the water-bath for fifteen minutes, the precipitated barium sulphate is washed with hot water by decantation, filtered off, ignited, and weighed.

An alternative dry method for sulphur is to mix 0.5 grm. of the finely powdered sample with 5 grm. of sodium peroxide in a nickel crucible which has been coated inside with a layer of fused caustic soda. The crucible is heated gently until the vigorous reaction commences. The melt is extracted with water, and acidified with hydrochloric acid. Further procedure is as above.

Spanish pyrites contains 3-4 per cent. of copper, which may be determined as follows: 5 grm. of the finely powdered sample are dissolved carefully in 60 cc. of nitric acid (Sp. Gr. 1.2) and the liquid evaporated until white fumes are evolved. The residue is dissolved in 50 cc. of concentrated hydrochloric acid, and the solution boiled after addition of 2 grm. of sodium hypophosphite to remove arsenic and reduce any ferric salt present. The copper and lead are precipitated as sulphides by hydrogen sulphide or sodium thiosulphate, the sulphide precipitate dissolved in nitric acid, and lead removed from the solution by evaporating with sulphuric acid. The copper in the filtrate is estimated by thiosulphate or by the electrolytic method (see Vol. I); in the latter case, 0.01 per cent. is subtracted from the copper content so obtained to correct for the antimony and bismuth present.

Arsenic is estimated by dissolving 0.5 grm. of the sample in nitric acid, evaporating to dryness after adding 4 grm. of sodium carbonate, and fusing with 4 grm. of potassium nitrate. The melt is extracted with hot water, acidified, carbon dioxide boiled off, the liquid neutralised with ammonia, and silver nitrate added. The silver arsenate is filtered off, dissolved in nitric acid, and the silver in the solution estimated.



## Sulphuric Acid.

(W. C. Ferguson and H. P. Talbot)

Adopted by the Manufacturing Chemists' Association  
of the U.S., 1904.

| °Baumé. | Sp. Gr. $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %H <sub>2</sub> SO <sub>4</sub> | °Baumé. | Sp. Gr. $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %H <sub>2</sub> SO <sub>4</sub> |
|---------|---|---------------------------------|---------|---|---------------------------------|
| 0       | 1.0000  | 0.00                            | 30      | 1.2609  | 34.63                           |
| 1       | 1.0069  | 1.02                            | 31      | 1.2719  | 35.93                           |
| 2       | 1.0140  | 2.08                            | 32      | 1.2832  | 37.26                           |
| 3       | 1.0211  | 3.13                            | 33      | 1.2946  | 38.58                           |
| 4       | 1.0284  | 4.21                            | 34      | 1.3063  | 39.92                           |
| 5       | 1.0357  | 5.28                            | 35      | 1.3182  | 41.27                           |
| 6       | 1.0432  | 6.37                            | 36      | 1.3303  | 42.63                           |
| 7       | 1.0507  | 7.45                            | 37      | 1.3426  | 43.99                           |
| 8       | 1.0584  | 8.55                            | 38      | 1.3551  | 45.35                           |
| 9       | 1.0662  | 9.66                            | 39      | 1.3679  | 46.72                           |
| 10      | 1.0741  | 10.77                           | 40      | 1.3810  | 48.10                           |
| 11      | 1.0821  | 11.89                           | 41      | 1.3942  | 49.47                           |
| 12      | 1.0902  | 13.01                           | 42      | 1.4078  | 50.87                           |
| 13      | 1.0985  | 14.13                           | 43      | 1.4216  | 52.26                           |
| 14      | 1.1069  | 15.25                           | 44      | 1.4356  | 53.66                           |
| 15      | 1.1154  | 16.38                           | 45      | 1.4500  | 55.07                           |
| 16      | 1.1240  | 17.53                           | 46      | 1.4646  | 56.48                           |
| 17      | 1.1328  | 18.71                           | 47      | 1.4796  | 57.90                           |
| 18      | 1.1417  | 19.89                           | 48      | 1.4948  | 59.32                           |
| 19      | 1.1508  | 21.07                           | 49      | 1.5104  | 60.75                           |
| 20      | 1.1600  | 22.25                           | 50      | 1.5263  | 62.18                           |
| 21      | 1.1694  | 23.43                           | 51      | 1.5422  | 63.36                           |
| 22      | 1.1789  | 24.61                           | 52      | 1.5591  | 65.61                           |
| 23      | 1.1885  | 25.81                           | 53      | 1.5761  | 66.63                           |
| 24      | 1.1983  | 27.03                           | 54      | 1.5934  | 68.13                           |
| 25      | 1.2083  | 28.28                           | 55      | 1.6111  | 69.65                           |
| 26      | 1.2185  | 29.53                           | 56      | 1.6292  | 71.17                           |
| 27      | 1.2288  | 30.79                           | 57      | 1.6477  | 72.75                           |
| 28      | 1.2393  | 32.05                           | 58      | 1.6667  | 74.36                           |
| 29      | 1.2500  | 33.33                           | 59      | 1.6860  | 75.99                           |



| °Baumé. | Sp. Gr. | $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %H <sub>2</sub> SO <sub>4</sub> | °Baumé. | Sp. Gr.          | $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %H <sub>2</sub> SO <sub>4</sub> |
|---------|---------|---|---------------------------------|---------|------------------|---|---------------------------------|
| 60      | 1.7059  |   | 77.67                           | .....   | 64 $\frac{1}{2}$ | 1.7957  | 86.33                           |
| 61      | 1.7262  |   | 79.43                           | .....   | 64 $\frac{1}{2}$ | 1.8012  | 87.04                           |
| 62      | 1.7470  |   | 81.30                           | .....   | 64 $\frac{3}{4}$ | 1.8068  | 87.81                           |
| 63      | 1.7683  |   | 83.34                           | .....   | 65               | 1.8125  | 88.65                           |
| 64      | 1.7901  |   | 85.86                           | .....   | 65 $\frac{1}{4}$ | 1.8182  | 89.55                           |
|         |         |   |                                 |         | 65 $\frac{1}{2}$ | 1.8239  | 90.60                           |
|         |         |   |                                 |         | 65 $\frac{3}{4}$ | 1.8297  | 91.80                           |
|         |         |   |                                 |         | 66               | 1.8354  | 93.19                           |

### ALLOWANCE FOR TEMPERATURES.

|                          |  |
|--------------------------|--|
| At 10° Bé. correction of | .029° Bé. or .00023 Sp. Gr. for every 1° F.  |
| At 20° Bé. correction of | .036° Bé. or .00034 Sp. Gr. for every 1° F.  |
| At 30° Bé. correction of | .035° Bé. or .00039 Sp. Gr. for every 1° F.  |
| At 40° Bé. correction of | .031° Bé. or .00041 Sp. Gr. for every 1° F.  |
| At 50° Bé. correction of | .028° Bé. or .00045 Sp. Gr. for every 1° F.  |
| At 60° Bé. correction of | .026° Bé. or .00053 Sp. Gr. for every 1° F.  |
| At 63° Bé. correction of | .026° Bé. or .00057 Sp. Gr. for every 1° F.  |
| At 66° Bé. correction of | .0235° Bé. or .00054 Sp. Gr. for every 1° F. |

For temperatures above 60° F., the correction is added to the observed indication; below 60° F., subtracted.

### Analysis of Oleum.

### I. Free SO<sub>3</sub>.

(a) 20% oleum. A quantity of the oleum is drawn up into a Lunge weighing pipette and the pipette is weighed. About 2 grm. of the oleum is then dropped into 200–300 cc. of water, the pipette is re-weighed, and the acid titrated with normal caustic soda solution, using methyl orange as indicator.

(b) 65% oleum. A bulb about  $\frac{1}{2}$ " diam. is blown on to the end of a piece of thin glass tubing, which is then drawn out to form a narrow stem about 3" long. The bulb is weighed and the open end of the stem placed below the surface of the oleum. The bulb is gently heated to expel some of the air, and then allowed to cool so that 2—3 grm. of the oleum enters the bulb. The stem is then sealed and dried, the bulb is re-weighed, and introduced into a stoppered bottle containing about 300 cc. of water. The stopper is fitted firmly, and the bottle shaken thoroughly until the bulb is broken and all white fumes are absorbed. The acid is then titrated with normal caustic soda using methyl orange as indicator.

*Example.*

Weight of fuming acid = 1.5125 grm.

$N$  caustic soda required (1 cc. = 0.04 grm.  $\text{SO}_3$ ) = 33.6 cc.  
= 1.344 grm.  $\text{SO}_3$ .

$$\text{H}_2\text{O combined with SO}_3 = 1.5125 - 1.344 = 0.1685 \text{ grm.}$$

Amount of  $\text{SO}_3$  required to combine with 0.1685 grm.

$$\text{H}_2\text{O} = 0.1685 \times \frac{80}{18} = 0.749 \text{ grm. SO}_3.$$
$$\text{Free SO}_3 = 1.344 - 0.749 = 0.595 \text{ grm. SO}_3.$$

$$\% \text{ Free SO}_3 = \frac{0.595 \times 100}{1.5125} = 39.3\%$$

## II. Sulphur dioxide.

10 cc. of the oleum is run slowly into about 500 cc. of water, the acid almost neutralised with sodium carbonate, and the liquid made neutral with sodium bicarbonate. The sulphur dioxide is then estimated by titration with deci-normal iodine solution.

### III. Nitric acid

This is usually estimated in 5 or 10 cc. of the oleum in a nitrometer (see "Gas Analysis" section). Using 5 cc. of the oleum at the ordinary temperature it may be taken that

1 cc. NO gas = 0.029% HNO<sub>3</sub>.

# Percentage of SO<sub>3</sub> in Fuming Sulphuric Acid.

% Free SO<sub>3</sub> = (% found by titrating - 81.6326) × 5.4444;  
 or, more accurately, = (% found by titrating - 81.6306) × 5.4438.

| Contains        |                                |                 | Contains        |                                |                 | Contains        |                                |                 |
|-----------------|--------------------------------|-----------------|-----------------|--------------------------------|-----------------|-----------------|--------------------------------|-----------------|
| Found by        |                                | %               | Found by        |                                | %               | Found by        |                                | %               |
| Titration       |                                | Free            | Titration       |                                | Free            | Titration       |                                | Free            |
| SO <sub>3</sub> | H <sub>2</sub> SO <sub>4</sub> | SO <sub>3</sub> | SO <sub>3</sub> | H <sub>2</sub> SO <sub>4</sub> | SO <sub>3</sub> | SO <sub>3</sub> | H <sub>2</sub> SO <sub>4</sub> | SO <sub>3</sub> |
| 81.6326         | 100                            | 0               | 87.8775         | 66                             | 34              | 94.1224         | 32                             | 68              |
| 81.8163         | 99                             | 1               | 88.0612         | 65                             | 35              | 94.3061         | 31                             | 69              |
| 82.0000         | 98                             | 2               | 88.2448         | 64                             | 36              | 94.4897         | 30                             | 70              |
| 82.1836         | 97                             | 3               | 88.4285         | 63                             | 37              | 94.6734         | 29                             | 71              |
| 82.3674         | 96                             | 4               | 88.6122         | 62                             | 38              | 94.8571         | 28                             | 72              |
| 82.5510         | 95                             | 5               | 88.7959         | 61                             | 39              | 95.0408         | 27                             | 73              |
| 82.7346         | 94                             | 6               | 88.9795         | 60                             | 40              | 95.2244         | 26                             | 74              |
| 82.9183         | 93                             | 7               | 89.1632         | 59                             | 41              | 95.4081         | 25                             | 75              |
| 83.1020         | 92                             | 8               | 89.3469         | 58                             | 42              | 95.5918         | 24                             | 76              |
| 83.2857         | 91                             | 9               | 89.5306         | 57                             | 43              | 95.7755         | 23                             | 77              |
| 83.4693         | 90                             | 10              | 89.7142         | 56                             | 44              | 95.9591         | 22                             | 78              |
| 83.6530         | 89                             | 11              | 89.8979         | 55                             | 45              | 96.1428         | 21                             | 79              |
| 83.8367         | 88                             | 12              | 90.0816         | 54                             | 46              | 96.3265         | 20                             | 80              |
| 84.0204         | 87                             | 13              | 90.2653         | 53                             | 47              | 96.5102         | 19                             | 81              |
| 84.2040         | 86                             | 14              | 90.4489         | 52                             | 48              | 96.6938         | 18                             | 82              |
| 84.3877         | 85                             | 15              | 90.6326         | 51                             | 49              | 96.8775         | 17                             | 83              |
| 84.5714         | 84                             | 16              | 90.8163         | 50                             | 50              | 97.0612         | 16                             | 84              |
| 84.7551         | 83                             | 17              | 91.0000         | 49                             | 51              | 97.2448         | 15                             | 85              |
| 84.9387         | 82                             | 18              | 91.1836         | 48                             | 52              | 97.4285         | 14                             | 86              |
| 85.1224         | 81                             | 19              | 91.3673         | 47                             | 53              | 97.6122         | 13                             | 87              |
| 85.3061         | 80                             | 20              | 91.5510         | 46                             | 54              | 97.7959         | 12                             | 88              |
| 85.4897         | 79                             | 21              | 91.7346         | 45                             | 55              | 97.9795         | 11                             | 89              |
| 85.6734         | 78                             | 22              | 91.9183         | 44                             | 56              | 98.1632         | 10                             | 90              |
| 85.8571         | 77                             | 23              | 92.1020         | 43                             | 57              | 98.3469         | 9                              | 91              |
| 86.0408         | 76                             | 24              | 92.2857         | 42                             | 58              | 98.5306         | 8                              | 92              |
| 86.2244         | 75                             | 25              | 92.4693         | 41                             | 59              | 98.7142         | 7                              | 93              |
| 86.4081         | 74                             | 26              | 92.6530         | 40                             | 60              | 98.8979         | 6                              | 94              |
| 86.5918         | 73                             | 27              | 92.8367         | 39                             | 61              | 99.0816         | 5                              | 95              |
| 86.7755         | 72                             | 28              | 93.0204         | 38                             | 62              | 99.2753         | 4                              | 96              |
| 86.9591         | 71                             | 29              | 93.2040         | 37                             | 63              | 99.4489         | 3                              | 97              |
| 87.1428         | 70                             | 30              | 93.3877         | 36                             | 64              | 99.6326         | 2                              | 98              |
| 87.3265         | 69                             | 31              | 93.5714         | 35                             | 65              | 99.8163         | 1                              | 99              |
| 87.5102         | 68                             | 32              | 93.7551         | 34                             | 66              |                 |                                |                 |
| 87.6938         | 67                             | 33              | 93.9389         | 33                             | 67              |                 |                                |                 |

## Boiling-points of Various Concentrations of Sulphuric Acid (Lunge).

| % $\text{H}_2\text{SO}_4$ | Sp. Gr. | B.Pt.   | % $\text{H}_2\text{SO}_4$ | Sp. Gr. | B.Pt.   |
|---------------------------|---------|---------|---------------------------|---------|---------|
| 5                         | 1.031   | 101° C. | 70                        | 1.615   | 170° C. |
| 10                        | 1.069   | 102     | 72                        | 1.639   | 174.5   |
| 15                        | 1.107   | 103.5   | 74                        | 1.661   | 180.5   |
| 20                        | 1.147   | 105     | 76                        | 1.688   | 189     |
| 25                        | 1.184   | 106.5   | 78                        | 1.710   | 199     |
| 30                        | 1.224   | 108     | 80                        | 1.733   | 207     |
| 35                        | 1.265   | 110     | 82                        | 1.758   | 218.5   |
| 40                        | 1.307   | 114     | 84                        | 1.773   | 227     |
| 45                        | 1.352   | 118.5   | 86                        | 1.791   | 238.5   |
| 50                        | 1.399   | 124     | 88                        | 1.807   | 251.5   |
| 53                        | 1.428   | 128.5   | 90                        | 1.818   | 262.5   |
| 56                        | 1.459   | 133     | 91                        | 1.824   | 268     |
| 60                        | 1.503   | 141.5   | 92                        | 1.830   | 274.5   |
| 62.5                      | 1.530   | 147     | 93                        | 1.834   | 281.5   |
| 65                        | 1.557   | 153.5   | 94                        | 1.837   | 288.5   |
| 67.5                      | 1.585   | 161     | 95                        | 1.840   | 295     |

## Boiling-point of Concentrated Sulphuric Acid and of Oleum (Knietzsch).

| % $\text{H}_2\text{SO}_4$ | Total $\text{SO}_3$ % | Free $\text{SO}_3$ % | B.Pt. °C. at | mm. |
|---------------------------|-----------------------|----------------------|--------------|-----|
| 61.69                     | 50.36                 | -                    | 140          | 750 |
| 70.90                     | 57.88                 | -                    | 162          | 750 |
| 81.49                     | 66.44                 | -                    | 202          | 750 |
| 89.23                     | 72.84                 | -                    | 240          | 750 |
| 96.26                     | 78.56                 | -                    | 292          | 750 |
| 98.54                     | 80.44                 | -                    | 317          | 750 |
| 99.91                     | 81.56                 | -                    | 273          | 753 |
| -                         | 82.3                  | 3.64                 | 212          | 759 |
| -                         | 83.4                  | 9.63                 | 170          | 759 |
| -                         | 86.45                 | 26.23                | 125          | 759 |
| -                         | 89.5                  | 42.84                | 92           | 759 |
| -                         | 93.24                 | 63.20                | 60           | 759 |
| -                         | 99.5                  | 97.2                 | 43           | 759 |

# Solidifying point of Sulphuric Acid and Oleum.

| Sulphuric acid.      |                                     |              | Oleum.               |                           |              |
|----------------------|-------------------------------------|--------------|----------------------|---------------------------|--------------|
| %<br>SO <sub>3</sub> | %<br>H <sub>2</sub> SO <sub>4</sub> | S.pt.<br>°C. | %<br>SO <sub>3</sub> | %<br>Free SO <sub>3</sub> | S.pt.<br>°C. |
| 1                    | 1.22                                | - 0.6        | 61                   | 74.72                     | -40.0        |
| 2                    | 2.45                                | - 1.0        | 62                   | 75.95                     | -20.0        |
| 3                    | 3.68                                | - 1.7        | 63                   | 77.18                     | -11.5        |
| 4                    | 4.90                                | - 2.0        | 64                   | 78.40                     | - 4.8        |
| 5                    | 6.13                                | - 2.7        | 65                   | 79.63                     | - 4.2        |
| 6                    | 7.35                                | - 3.6        | 66                   | 80.85                     | + 1.2        |
| 7                    | 8.58                                | - 4.4        | 67                   | 82.08                     | + 8.0        |
| 8                    | 9.80                                | - 5.3        | 68                   | 83.39                     | + 8.0        |
| 9                    | 11.03                               | - 6.0        | 69                   | 84.53                     | + 7.0        |
| 10                   | 12.25                               | - 6.7        | 70                   | 85.75                     | + 4.0        |
| 11                   | 13.47                               | - 7.2        | 71                   | 86.97                     | - 1.0        |
| 12                   | 14.70                               | - 7.9        | 72                   | 88.20                     | - 7.2        |
| 13                   | 15.92                               | - 8.2        | 73                   | 89.43                     | -16.2        |
| 14                   | 17.15                               | - 9.0        | 74                   | 90.65                     | -25.0        |
| 15                   | 18.37                               | - 9.3        | 75                   | 91.87                     | -34.0        |
| 16                   | 19.60                               | - 9.8        | 76                   | 93.10                     | -32.0        |
| 17                   | 20.82                               | -11.4        | 77                   | 94.83                     | -28.2        |
| 18                   | 22.05                               | -13.2        | 78                   | 95.05                     | -16.5        |
| 19                   | 23.27                               | -15.2        | 79                   | 96.78                     | - 5.2        |
| 20                   | 24.50                               | -17.1        | 80                   | 98.00                     | + 3.0        |
| 21                   | 25.72                               | -22.5        | 81                   | 99.25                     | + 7.0        |
| 22                   | 26.95                               | -31.0        | 81.63                | 100.00                    | +10.0        |
| 23                   | 28.17                               | -40.1        |                      |                           |              |

## Preparation of Fuming Sulphuric Acid of required strength.

Gnehm gives the following formula:  $x = 100 \frac{b - a}{a - c}$

where  $x$  = amount of ordinary sulphuric acid to be added to 100 parts of the fuming acid available,

$a$  = total SO<sub>3</sub> per cent. in the required acid,

$b$  = " " fuming acid available,

$c$  = SO<sub>3</sub> in the ordinary sulphuric acid =  $0.816 \times \% \text{H}_2\text{SO}_4$ .

Gerster gives the following formula:—

$$x = \frac{100(a - b)}{444 + b - 4.44c}$$

where  $x$  = amount of ordinary sulphuric acid to be added to 100 g. of the fuming acid available.

$a$  = free SO<sub>3</sub> per cent. in the fuming acid available.

$b$  = free SO<sub>2</sub> " " " " required.

$c$  = H<sub>2</sub>SO<sub>4</sub> " " ordinary sulphuric acid.

# Nitric Acid. (W. C. Ferguson).

Adopted by the Manufacturing Chemists' Association of the U.S.,  
1904.

| °Baumé. | Sp. Gr. | $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ %HNO <sub>3</sub> . | °Baumé. | Sp. Gr. | $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ %HNO <sub>3</sub> . |       |
|---------|---------|---|---------|---------|---|-------|
| - 10.00 | 1.0741  | 12.86   | .....   | 25.00   | 1.2083  | 33.42 |
| 10.50   | 1.0781  | 13.49   | .....   | 25.50   | 1.2134  | 34.17 |
| 11.00   | 1.0821  | 14.13   | .....   | 26.00   | 1.2185  | 34.94 |
| 11.50   | 1.0861  | 14.76   | .....   | 26.50   | 1.2236  | 35.70 |
| 12.00   | 1.0902  | 15.41   | .....   | 27.00   | 1.2288  | 36.48 |
| 12.50   | 1.0943  | 16.05   | .....   | 27.50   | 1.2340  | 37.26 |
| 13.00   | 1.0985  | 16.72   | .....   | 28.00   | 1.2393  | 38.06 |
| 13.50   | 1.1027  | 17.38   | .....   | 28.50   | 1.2446  | 38.85 |
| 14.00   | 1.1069  | 18.04   | .....   | 29.00   | 1.2500  | 39.66 |
| 14.50   | 1.1111  | 18.70   | .....   | 29.50   | 1.2554  | 40.47 |
| 15.00   | 1.1154  | 19.36   | .....   | 30.00   | 1.2609  | 41.30 |
| 15.50   | 1.1197  | 20.02   | .....   | 30.50   | 1.2664  | 42.14 |
| 16.00   | 1.1240  | 20.69   | .....   | 31.00   | 1.2719  | 43.00 |
| 16.50   | 1.1284  | 21.36   | .....   | 31.50   | 1.2775  | 43.89 |
| 17.00   | 1.1328  | 22.04   | .....   | 32.00   | 1.2832  | 44.78 |
| 17.50   | 1.1373  | 22.74   | .....   | 32.50   | 1.2889  | 45.68 |
| 18.00   | 1.1417  | 23.42   | .....   | 33.00   | 1.2946  | 46.58 |
| 18.50   | 1.1462  | 24.11   | .....   | 33.50   | 1.3004  | 47.49 |
| 19.00   | 1.1508  | 24.82   | .....   | 34.00   | 1.3063  | 48.42 |
| 19.50   | 1.1554  | 25.53   | .....   | 34.50   | 1.3122  | 49.35 |
| 20.00   | 1.1600  | 26.24   | .....   | 35.00   | 1.3182  | 50.32 |
| 20.50   | 1.1647  | 26.96   | .....   | 35.50   | 1.3242  | 51.30 |
| 21.00   | 1.1694  | 27.67   | .....   | 36.00   | 1.3303  | 52.30 |
| 21.50   | 1.1741  | 28.36   | .....   | 36.50   | 1.3364  | 53.32 |
| 22.00   | 1.1789  | 29.07   | .....   | 37.00   | 1.3426  | 54.36 |
| 22.50   | 1.1837  | 29.78   | .....   | 37.50   | 1.3488  | 55.43 |
| 23.00   | 1.1885  | 30.49   | .....   | 38.00   | 1.3551  | 56.52 |
| 23.50   | 1.1934  | 31.21   | .....   | 38.50   | 1.3615  | 57.65 |
| 24.00   | 1.1983  | 31.94   | .....   | 39.00   | 1.3679  | 58.82 |
| 24.50   | 1.2033  | 32.68   | .....   | 39.50   | 1.3744  | 60.06 |

| °Baumé. | Sp. Gr. $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %HNO <sub>3</sub> . | °Baumé. | Sp. Gr. $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %HNO <sub>3</sub> . |
|---------|---|---------------------|---------|---|---------------------|
| 40.00   | 1.3810  | 61.38               | 45.00   | 1.4500  | 77.17               |
| 40.25   | 1.3843  | 62.07               | 45.25   | 1.4536  | 78.07               |
| 40.50   | 1.3876  | 62.77               | 45.50   | 1.4573  | 79.03               |
| 40.75   | 1.3909  | 63.48               | 45.75   | 1.4610  | 80.04               |
| 41.00   | 1.3942  | 64.20               | 46.00   | 1.4646  | 81.08               |
| 41.25   | 1.3976  | 64.93               | 46.25   | 1.4684  | 82.18               |
| 41.50   | 1.4010  | 65.67               | 46.50   | 1.4721  | 83.33               |
| 41.75   | 1.4044  | 66.42               | 46.75   | 1.4758  | 84.48               |
| 42.00   | 1.4078  | 67.18               | 47.00   | 1.4796  | 85.70               |
| 42.25   | 1.4112  | 67.95               | 47.25   | 1.4834  | 86.98               |
| 42.50   | 1.4146  | 68.73               | 47.50   | 1.4872  | 88.32               |
| 42.75   | 1.4181  | 69.52               | 47.75   | 1.4910  | 89.76               |
| 43.00   | 1.4216  | 70.33               | 48.00   | 1.4948  | 91.35               |
| 43.25   | 1.4251  | 71.15               | 48.25   | 1.4987  | 93.13               |
| 43.50   | 1.4286  | 71.98               | 48.50   | 1.5026  | 95.11               |
| 43.75   | 1.4321  | 72.82               |         |   |                     |
| 44.00   | 1.4356  | 73.67               |         |   |                     |
| 44.25   | 1.4392  | 74.53               |         |   |                     |
| 44.50   | 1.4428  | 75.40               |         |   |                     |
| 44.75   | 1.4464  | 76.28               |         |   |                     |

### ALLOWANCE FOR TEMPERATURE.

- At from 10° to 20° Bé. correction of 1/30° Bé  
or .00029 Sp. Gr. for every 1° F.
- At from 20° to 30° Bé. correction of 1/23° Bé.  
or .00044 Sp. Gr. for every 1° F.
- At from 30° to 40° Bé. correction of 1/20° Bé.  
or .00060 Sp. Gr. for every 1° F.
- At from 40° to 48.5° Bé. correction of 1/17° Bé.  
or .00084 Sp. Gr. for every 1° F.



## Hydrochloric Acid.

(W. C. Ferguson).

Adopted by the Manufacturing Chemists' Association of the U.S.,  
1903.

| °Baumé. | Sp. Gr. $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %HCl. | °Baumé. | Sp. Gr. $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %HCl. |
|---------|---|-------|---------|---|-------|
| 1.00    | 1.0069  | 1.40  | 16.70   | 1.1301  | 25.72 |
| 2.00    | 1.0140  | 2.82  | 16.80   | 1.1310  | 25.89 |
| 3.00    | 1.0211  | 4.25  | 16.90   | 1.1319  | 26.05 |
| 4.00    | 1.0284  | 5.69  | 17.00   | 1.1328  | 26.22 |
| 5.00    | 1.0357  | 7.15  | 17.10   | 1.1336  | 26.39 |
| 6.00    | 1.0432  | 8.64  | 17.20   | 1.1345  | 26.56 |
| 7.00    | 1.0507  | 10.17 | 17.30   | 1.1354  | 26.73 |
| 8.00    | 1.0584  | 11.71 | 17.40   | 1.1363  | 26.90 |
| 9.00    | 1.0662  | 13.26 | 17.50   | 1.1372  | 27.07 |
| 10.00   | 1.0741  | 14.83 | 17.60   | 1.1381  | 27.24 |
| 10.50   | 1.0781  | 15.62 | 17.70   | 1.1390  | 27.41 |
| 11.00   | 1.0821  | 16.41 | 17.80   | 1.1399  | 27.58 |
| 11.50   | 1.0861  | 17.21 | 17.90   | 1.1408  | 27.75 |
| 12.00   | 1.0902  | 18.01 | 18.00   | 1.1417  | 27.92 |
| 12.50   | 1.0943  | 18.82 | 18.10   | 1.1426  | 28.09 |
| 12.75   | 1.0964  | 19.22 | 18.20   | 1.1435  | 28.26 |
| 13.00   | 1.0985  | 19.63 | 18.30   | 1.1444  | 28.44 |
| 13.25   | 1.1006  | 20.04 | 18.40   | 1.1453  | 28.61 |
| 13.50   | 1.1027  | 20.45 | 18.50   | 1.1462  | 28.78 |
| 13.75   | 1.1048  | 20.86 | 18.60   | 1.1471  | 28.95 |
| 14.00   | 1.1069  | 21.27 | 18.70   | 1.1480  | 29.13 |
| 14.25   | 1.1090  | 21.68 | 18.80   | 1.1489  | 29.30 |
| 14.50   | 1.1111  | 22.09 | 18.90   | 1.1498  | 29.48 |
| 14.75   | 1.1132  | 22.50 | 19.00   | 1.1508  | 29.65 |
| 15.00   | 1.1154  | 22.92 | 19.10   | 1.1517  | 29.83 |
| 15.25   | 1.1176  | 23.33 | 19.20   | 1.1526  | 30.00 |
| 15.50   | 1.1197  | 23.75 | 19.30   | 1.1535  | 30.18 |
| 15.75   | 1.1219  | 24.16 | 19.40   | 1.1544  | 30.35 |
| 16.00   | 1.1240  | 24.57 | 19.50   | 1.1554  | 30.53 |
| 16.10   | 1.1248  | 24.73 | 19.60   | 1.1563  | 30.71 |
| 16.20   | 1.1256  | 24.90 | 19.70   | 1.1572  | 30.90 |
| 16.30   | 1.1265  | 25.06 | 19.80   | 1.1581  | 31.08 |
| 16.40   | 1.1274  | 25.23 | 19.90   | 1.1590  | 31.27 |
| 16.50   | 1.1283  | 25.39 | 20.00   | 1.1600  | 31.45 |
| 16.60   | 1.1292  | 25.56 | 20.10   | 1.1609  | 31.64 |

| °Baumé. | Sp. Gr. | $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %HCl. | °Baumé. | Sp. Gr. | $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %HCl. |
|---------|---------|---|-------|---------|---------|---|-------|
| 20.20   | 1.1619  |   | 31.82 | .....   | 22.20   | 1.1808  | 35.59 |
| 20.30   | 1.1628  |   | 32.01 | .....   | 22.30   | 1.1817  | 35.78 |
| 20.40   | 1.1637  |   | 32.19 | .....   | 22.40   | 1.1827  | 35.97 |
| 20.50   | 1.1647  |   | 32.38 | .....   | 22.50   | 1.1836  | 36.16 |
| 20.60   | 1.1656  |   | 32.56 | .....   | 22.60   | 1.1846  | 36.35 |
| 20.70   | 1.1666  |   | 32.75 | .....   | 22.70   | 1.1856  | 36.54 |
| 20.80   | 1.1675  |   | 32.93 | .....   | 22.80   | 1.1866  | 36.73 |
| 20.90   | 1.1684  |   | 33.12 | .....   | 22.90   | 1.1875  | 36.93 |
| 21.00   | 1.1694  |   | 33.31 | .....   | 23.00   | 1.1885  | 37.14 |
| 21.10   | 1.1703  |   | 33.50 | .....   | 23.10   | 1.1895  | 37.36 |
| 21.20   | 1.1713  |   | 33.69 | .....   | 23.20   | 1.1904  | 37.58 |
| 21.30   | 1.1722  |   | 33.88 | .....   | 23.30   | 1.1914  | 37.80 |
| 21.40   | 1.1732  |   | 34.07 | .....   | 23.40   | 1.1924  | 38.03 |
| 21.50   | 1.1741  |   | 34.26 | .....   | 23.50   | 1.1934  | 38.26 |
| 21.60   | 1.1751  |   | 34.45 | .....   | 23.60   | 1.1944  | 38.49 |
| 21.70   | 1.1760  |   | 34.64 | .....   | 23.70   | 1.1953  | 38.72 |
| 21.80   | 1.1770  |   | 34.83 | .....   | 23.80   | 1.1963  | 38.95 |
| 21.90   | 1.1779  |   | 35.02 | .....   | 23.90   | 1.1973  | 39.18 |
| 22.00   | 1.1789  |   | 35.21 | .....   | 24.00   | 1.1983  | 39.41 |
| 22.10   | 1.1798  |   | 35.40 | .....   | 24.10   | 1.1993  | 39.64 |

### ALLOWANCE FOR TEMPERATURE.

At 10° to 15° Bé. correction of 1/40° Bé.

or .0002 Sp. Gr. for every 1° F.

At 10° to 22° Bé. correction of 1/30° Bé.

or .0003 Sp. Gr. for every 1° F.

At 22° to 25° Bé. correction of 1/28° Bé.

or .00035 Sp. Gr. for every 1° F.

## Alkali Manufacture.

Table for Comparing Different Systems of Alkalimetry for Caustic Soda.

| Caustic Soda<br>% NaOH | Actual Alkali<br>% Na <sub>2</sub> O | Newcastle Test<br>% Na <sub>2</sub> O | N. Y. & Liv.<br>% Na <sub>2</sub> O |
|------------------------|--------------------------------------|---------------------------------------|-------------------------------------|
| 74.83                  | 58.0                                 | 58.76                                 | 59.87                               |
| 75.48                  | 58.5                                 | 59.27                                 | 60.38                               |
| 76.12                  | 59.0                                 | 59.77                                 | 60.90                               |
| 76.77                  | 59.5                                 | 60.28                                 | 61.42                               |
| 77.40                  | 60.0                                 | 60.79                                 | 61.93                               |
| 78.05                  | 60.5                                 | 61.30                                 | 62.45                               |
| 78.70                  | 61.0                                 | 61.80                                 | 62.97                               |
| 79.35                  | 61.5                                 | 62.31                                 | 63.48                               |
| 80.00                  | 62.0                                 | 62.82                                 | 64.00                               |
| 80.65                  | 62.5                                 | 63.32                                 | 64.52                               |
| 81.29                  | 63.0                                 | 63.83                                 | 65.03                               |
| 81.94                  | 63.5                                 | 64.33                                 | 65.55                               |
| 82.58                  | 64.0                                 | 64.84                                 | 66.06                               |
| 83.23                  | 64.5                                 | 65.35                                 | 66.58                               |
| 83.87                  | 65.0                                 | 65.85                                 | 67.10                               |
| 84.52                  | 65.5                                 | 66.36                                 | 67.61                               |
| 85.16                  | 66.0                                 | 66.87                                 | 68.13                               |
| 85.81                  | 66.5                                 | 67.37                                 | 68.65                               |
| 86.45                  | 67.0                                 | 67.88                                 | 69.16                               |
| 87.10                  | 67.5                                 | 68.39                                 | 69.68                               |
| 87.74                  | 68.0                                 | 68.89                                 | 70.19                               |
| 88.39                  | 68.5                                 | 69.40                                 | 70.71                               |
| 89.03                  | 69.0                                 | 69.91                                 | 71.23                               |
| 89.67                  | 69.5                                 | 70.41                                 | 71.74                               |
| 90.30                  | 70.0                                 | 70.92                                 | 72.26                               |
| 90.95                  | 70.5                                 | 71.43                                 | 72.77                               |
| 91.60                  | 71.0                                 | 71.93                                 | 73.29                               |
| 92.25                  | 71.5                                 | 72.44                                 | 73.81                               |
| 92.90                  | 72.0                                 | 72.95                                 | 74.32                               |
| 93.55                  | 72.5                                 | 73.45                                 | 74.84                               |
| 94.19                  | 73.0                                 | 73.96                                 | 75.35                               |
| 94.84                  | 73.5                                 | 74.47                                 | 75.87                               |
| 95.48                  | 74.0                                 | 74.97                                 | 76.39                               |
| 96.13                  | 74.5                                 | 75.48                                 | 76.90                               |
| 96.77                  | 75.0                                 | 75.99                                 | 77.42                               |
| 97.32                  | 75.5                                 | 76.49                                 | 77.94                               |
| 98.06                  | 76.0                                 | 77.00                                 | 78.45                               |
| 98.71                  | 76.5                                 | 77.51                                 | 78.97                               |
| 99.35                  | 77.0                                 | 78.01                                 | 79.49                               |
| 100.00                 | 77.5                                 | 78.52                                 | 80.00                               |

### Commercial Alkalimetric Degrees.

Real soda (Gay-Lussac degrees)=percentage  $\text{Na}_2\text{O}$  (calculated to correct equivalent of  $\text{Na}_2\text{CO}_3$ , viz., 53.05).

English or Newcastle degrees=percentage  $\text{Na}_2\text{O}$  (calculated to an incorrect equivalent of  $\text{Na}_2\text{CO}_3$ , viz., 54).

German degrees=percentage  $\text{Na}_2\text{CO}_3$ .

Descroizilles degrees=amount of  $\text{H}_2\text{SO}_4$  neutralised by 100 parts of alkali. (Used in France and Belgium.)

Table for Comparing Different Systems of Alkalimetry  
for Soda Ash.

| Soda Ash<br>% $\text{Na}_2\text{CO}_3$ | Actual Alkali<br>% $\text{Na}_2\text{C}$ | Newcastle Test<br>% $\text{Na}_2\text{O}$ | N. Y. & Liv.<br>% $\text{Na}_2\text{O}$ |
|--|--|---|---|
| 79.51                                  | 46.5                                     | 47.11                                     | 48.00                                   |
| 80.37                                  | 47.0                                     | 47.62                                     | 48.51                                   |
| 81.22                                  | 47.5                                     | 48.12                                     | 49.03                                   |
| 82.07                                  | 48.0                                     | 48.63                                     | 49.54                                   |
| 82.93                                  | 48.5                                     | 49.14                                     | 50.06                                   |
| 83.78                                  | 49.0                                     | 49.64                                     | 50.58                                   |
| 84.64                                  | 49.5                                     | 50.15                                     | 51.09                                   |
| 85.48                                  | 50.0                                     | 50.66                                     | 51.61                                   |
| 86.34                                  | 50.5                                     | 51.16                                     | 52.12                                   |
| 87.19                                  | 51.0                                     | 51.67                                     | 52.64                                   |
| 88.05                                  | 51.5                                     | 52.18                                     | 53.16                                   |
| 88.90                                  | 52.0                                     | 52.68                                     | 53.67                                   |
| 89.76                                  | 52.5                                     | 53.19                                     | 54.19                                   |
| 90.61                                  | 53.0                                     | 53.70                                     | 54.70                                   |
| 91.47                                  | 53.5                                     | 54.20                                     | 55.22                                   |
| 92.32                                  | 54.0                                     | 54.71                                     | 55.74                                   |
| 93.18                                  | 54.5                                     | 55.22                                     | 56.25                                   |
| 94.03                                  | 55.0                                     | 55.72                                     | 56.77                                   |
| 94.89                                  | 55.5                                     | 56.23                                     | 57.29                                   |
| 95.74                                  | 56.0                                     | 56.74                                     | 57.80                                   |
| 96.60                                  | 56.5                                     | 57.24                                     | 58.32                                   |
| 97.45                                  | 57.0                                     | 57.75                                     | 58.83                                   |
| 98.31                                  | 57.5                                     | 58.26                                     | 59.35                                   |
| 99.16                                  | 58.0                                     | 58.76                                     | 59.87                                   |
| 100.00                                 | 58.5                                     | 59.27                                     | 60.38                                   |

**Valuation of Soda Ash.** 25 grm. of soda ash are dissolved in water, and made up to 250 cc.

(a) *In presence of bicarbonate.* 25 cc. of the solution are titrated in a porcelain dish with normal sulphuric acid, slowly and with stirring, with the point of the burette under the liquid, using phenolphthalein as indicator. As soon as carbonic acid is liberated the solution becomes colourless, that is, when the sodium carbonate has been converted into bicarbonate. Methyl orange is then added and the titration continued until the solution is acid. This converts all the bicarbonate (including that formed from the carbonate) into sulphate. The difference between the first and (larger) second volume will hence correspond to the bicarbonate present, and twice the first volume to the carbonate present.

(b) *In presence of caustic soda.* The above titrations are carried out. The first volume of acid used (with phenolphthalein) will be found to be larger than the second volume (using methyl orange). In this case the first volume corresponds to the neutralisation of the caustic soda and the conversion of the carbonate into bicarbonate. The difference between the two volumes hence corresponds to the caustic soda present, and twice the second volume to the carbonate present.

## Sodium Hydroxide Solutions.

(Lunge).

| Sp. Gr. $\frac{60^{\circ} \text{ F.}}{60^{\circ} \text{ F.}}$ | °Baumé. | °Twaddell. | % NaOH. | Grm. NaOH.<br>per litre. |
|---|---------|------------|---------|--------------------------|
| 1.007   | 1.0     | 1.4        | 0.61    | 6                        |
| 1.014   | 2.0     | 2.8        | 1.20    | 12                       |
| 1.022   | 3.1     | 4.4        | 2.00    | 21                       |
| 1.029   | 4.1     | 5.8        | 2.70    | 28                       |
| 1.036   | 5.1     | 7.2        | 3.35    | 35                       |
| 1.045   | 6.2     | 9.0        | 4.00    | 42                       |
| 1.052   | 7.2     | 10.4       | 4.64    | 49                       |
| 1.060   | 8.2     | 12.0       | 5.29    | 56                       |
| 1.067   | 9.1     | 13.4       | 5.87    | 63                       |
| 1.075   | 10.1    | 15.0       | 6.55    | 70                       |

| Sp. Gr. $\frac{60^{\circ} \text{ F.}}{60^{\circ} \text{ F.}}$ | °Baumé. | °Twaddell. | % NaOH. | Grm. NaOH.<br>per litre. |
|---|---------|------------|---------|--------------------------|
| 1.083   | 11.1    | 16.6       | 7.31    | 79                       |
| 1.091   | 12.1    | 18.2       | 8.00    | 87                       |
| 1.100   | 13.2    | 20.0       | 8.68    | 95                       |
| 1.108   | 14.1    | 21.6       | 9.42    | 104                      |
| 1.116   | 15.1    | 23.2       | 10.06   | 112                      |
| 1.125   | 16.1    | 25.0       | 10.97   | 123                      |
| 1.134   | 17.1    | 26.8       | 11.84   | 134                      |
| 1.142   | 18.0    | 28.4       | 12.64   | 144                      |
| 1.152   | 19.1    | 30.4       | 13.55   | 156                      |
| 1.162   | 20.2    | 32.4       | 14.37   | 167                      |
| 1.171   | 21.2    | 34.2       | 15.13   | 177                      |
| 1.180   | 22.1    | 36.0       | 15.91   | 188                      |
| 1.190   | 23.1    | 38.0       | 16.77   | 200                      |
| 1.200   | 24.2    | 40.0       | 17.67   | 212                      |
| 1.210   | 25.2    | 42.0       | 18.58   | 225                      |
| 1.220   | 26.1    | 44.0       | 19.58   | 239                      |
| 1.231   | 27.2    | 46.2       | 20.59   | 253                      |
| 1.241   | 28.2    | 48.2       | 21.42   | 266                      |
| 1.252   | 29.2    | 50.4       | 22.64   | 283                      |
| 1.263   | 30.2    | 52.6       | 23.67   | 299                      |
| 1.274   | 31.2    | 54.8       | 24.81   | 316                      |
| 1.285   | 32.2    | 57.0       | 25.80   | 332                      |
| 1.297   | 33.2    | 59.4       | 26.83   | 348                      |
| 1.308   | 34.1    | 61.6       | 27.80   | 364                      |
| 1.320   | 35.2    | 64.0       | 28.83   | 381                      |
| 1.332   | 36.1    | 66.4       | 29.93   | 399                      |
| 1.345   | 37.2    | 69.0       | 31.22   | 420                      |
| 1.357   | 38.1    | 71.4       | 32.47   | 441                      |
| 1.370   | 39.2    | 74.0       | 33.69   | 462                      |
| 1.383   | 40.2    | 76.6       | 34.96   | 483                      |
| 1.397   | 41.2    | 79.4       | 36.25   | 506                      |
| 1.410   | 42.2    | 82.0       | 37.47   | 528                      |
| 1.424   | 43.2    | 84.8       | 38.80   | 553                      |
| 1.438   | 44.2    | 87.6       | 39.99   | 575                      |
| 1.453   | 45.2    | 90.6       | 41.41   | 602                      |
| 1.468   | 46.2    | 93.6       | 42.83   | 629                      |
| 1.483   | 47.2    | 96.6       | 44.38   | 658                      |
| 1.498   | 48.2    | 99.6       | 46.15   | 691                      |
| 1.514   | 49.2    | 102.8      | 47.60   | 721                      |
| 1.530   | 50.2    | 106.0      | 49.02   | 750                      |

## Potassium Hydroxide Solutions.

(Lunge).

| Sp. Gr. $\frac{60^{\circ} \text{ F.}}{60^{\circ} \text{ F.}}$ | °Baumé. | °Twaddell. | % KOH. | Grm. KOH.<br>per litre. |
|---|---------|------------|--------|-------------------------|
| 1.007   | 1.0     | 1.4        | 0.9    | 9                       |
| 1.014   | 2.0     | 2.8        | 1.7    | 17                      |
| 1.022   | 3.1     | 4.4        | 2.6    | 26                      |
| 1.029   | 4.1     | 5.8        | 3.5    | 36                      |
| 1.037   | 5.2     | 7.4        | 4.5    | 46                      |
| 1.045   | 6.2     | 9.0        | 5.6    | 58                      |
| 1.052   | 7.2     | 10.4       | 6.4    | 67                      |
| 1.060   | 8.2     | 12.0       | 7.4    | 78                      |
| 1.067   | 9.1     | 13.4       | 8.2    | 83                      |
| 1.075   | 10.1    | 15.0       | 9.2    | 99                      |
| 1.083   | 11.1    | 16.6       | 10.1   | 109                     |
| 1.091   | 12.1    | 18.2       | 10.9   | 119                     |
| 1.100   | 13.2    | 20.0       | 12.0   | 132                     |
| 1.108   | 14.1    | 21.6       | 12.9   | 143                     |
| 1.116   | 15.1    | 23.2       | 13.8   | 153                     |
| 1.125   | 16.1    | 25.0       | 14.8   | 167                     |
| 1.134   | 17.1    | 26.8       | 15.7   | 178                     |
| 1.142   | 18.0    | 28.4       | 16.5   | 183                     |
| 1.152   | 19.1    | 30.4       | 17.6   | 203                     |
| 1.162   | 20.2    | 32.4       | 18.6   | 216                     |
| 1.171   | 21.2    | 34.2       | 19.5   | 228                     |
| 1.180   | 22.1    | 36.0       | 20.5   | 242                     |
| 1.190   | 23.1    | 38.0       | 21.4   | 255                     |
| 1.200   | 24.2    | 40.0       | 22.4   | 269                     |
| 1.210   | 25.2    | 42.0       | 23.3   | 282                     |
| 1.220   | 26.1    | 44.0       | 24.2   | 295                     |
| 1.231   | 27.2    | 46.2       | 25.1   | 309                     |
| 1.241   | 28.2    | 48.2       | 26.1   | 324                     |
| 1.252   | 29.2    | 50.4       | 27.0   | 338                     |



---

| Sp. Gr. $\frac{60^{\circ} \text{ F.}}{60^{\circ} \text{ F.}}$ | °Baumé. | °Twaddell. | % KOH. | Grm. KOH.<br>per litre. |
|---|---------|------------|--------|-------------------------|
| <hr/>   |         |            |        |                         |
| 1.263   | 30.2    | 52.6       | 28.0   | 353                     |
| 1.274   | 31.2    | 54.8       | 28.9   | 368                     |
| 1.285   | 32.2    | 57.0       | 29.8   | 385                     |
| 1.297   | 33.2    | 59.4       | 30.7   | 398                     |
| 1.308   | 34.1    | 61.6       | 31.8   | 416                     |
| 1.320   | 35.2    | 64.0       | 32.7   | 432                     |
| 1.332   | 36.1    | 66.4       | 33.7   | 449                     |
| 1.345   | 37.2    | 69.0       | 34.9   | 469                     |
| 1.357   | 38.1    | 71.4       | 35.9   | 487                     |
| 1.370   | 39.2    | 74.0       | 36.9   | 506                     |
| 1.383   | 40.2    | 76.6       | 37.8   | 522                     |
| 1.397   | 41.2    | 79.4       | 38.9   | 543                     |
| 1.410   | 42.2    | 82.0       | 39.9   | 563                     |
| 1.424   | 43.2    | 84.8       | 40.9   | 582                     |
| 1.438   | 44.2    | 87.6       | 42.1   | 605                     |
| 1.453   | 45.2    | 90.6       | 43.4   | 631                     |
| 1.468   | 46.2    | 93.6       | 44.6   | 655                     |
| 1.483   | 47.2    | 96.6       | 45.8   | 679                     |
| 1.498   | 48.2    | 99.6       | 47.1   | 706                     |
| 1.514   | 49.2    | 102.8      | 48.3   | 731                     |
| 1.530   | 50.2    | 106.0      | 49.4   | 756                     |
| 1.546   | 51.2    | 109.2      | 50.6   | 779                     |
| 1.563   | 52.2    | 112.6      | 51.9   | 811                     |
| 1.580   | 53.2    | 116.0      | 53.2   | 840                     |
| 1.597   | 54.2    | 119.4      | 54.5   | 870                     |
| 1.615   | 55.2    | 123.0      | 55.9   | 905                     |
| 1.634   | 56.3    | 126.8      | 57.5   | 940                     |

---

## Ammonia Solutions.

(W. C. Ferguson).

Adopted by the Manufacturing Chemists' Association of the U.S.  
1903.

| Sp. Gr. | $^{\circ}\text{Baumé.}$ | $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %NH <sub>3</sub> . | $^{\circ}\text{Baumé.}$ | Sp. Gr. | $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %NH <sub>3</sub> . |
|---------|-------------------------|---|--------------------|-------------------------|---------|---|--------------------|
| 10.00   | 1.0000                  | .00   | .....              | 18.75                   | .9412   |   | 15.37              |
| 10.25   | .9982                   | .40   | .....              | 19.00                   | .9396   |   | 15.84              |
| 10.50   | .9964                   | .80   | .....              | 19.25                   | .9380   |   | 16.32              |
| 10.75   | .9947                   | 1.21  | .....              | 19.50                   | .9365   |   | 16.80              |
| 11.00   | .9929                   | 1.62  | .....              | 19.75                   | .9349   |   | 17.28              |
| 11.25   | .9912                   | 2.04  | .....              | 20.00                   | .9333   |   | 17.76              |
| 11.50   | .9894                   | 2.46  | .....              | 20.25                   | .9318   |   | 18.24              |
| 11.75   | .9876                   | 2.88  | .....              | 20.50                   | .9302   |   | 18.72              |
| 12.00   | .9859                   | 3.30  | .....              | 20.75                   | .9287   |   | 19.20              |
| 12.25   | .9842                   | 3.73  | .....              | 21.00                   | .9272   |   | 19.68              |
| 12.50   | .9825                   | 4.16  | .....              | 21.25                   | .9256   |   | 20.16              |
| 12.75   | .9807                   | 4.59  | .....              | 21.50                   | .9241   |   | 20.64              |
| 13.00   | .9790                   | 5.02  | .....              | 21.75                   | .9226   |   | 21.12              |
| 13.25   | .9773                   | 5.45  | .....              | 22.00                   | .9211   |   | 21.60              |
| 13.50   | .9756                   | 5.88  | .....              | 22.25                   | .9195   |   | 22.08              |
| 13.75   | .9739                   | 6.31  | .....              | 22.50                   | .9180   |   | 22.56              |
| 14.00   | .9722                   | 6.74  | .....              | 22.75                   | .9165   |   | 23.04              |
| 14.25   | .9705                   | 7.17  | .....              | 23.00                   | .9150   |   | 23.52              |
| 14.50   | .9689                   | 7.61  | .....              | 23.25                   | .9135   |   | 24.01              |
| 14.75   | .9672                   | 8.05  | .....              | 23.50                   | .9121   |   | 24.50              |
| 15.00   | .9655                   | 8.49  | .....              | 23.75                   | .9106   |   | 24.99              |
| 15.25   | .9639                   | 8.93  | .....              | 24.00                   | .9091   |   | 25.48              |
| 15.50   | .9622                   | 9.38  | .....              | 24.25                   | .9076   |   | 25.97              |
| 15.75   | .9605                   | 9.83  | .....              | 24.50                   | .9061   |   | 26.46              |
| 16.00   | .9589                   | 10.28   | .....              | 24.75                   | .9047   |   | 26.95              |
| 16.25   | .9573                   | 10.73   | .....              | 25.00                   | .9032   |   | 27.44              |
| 16.50   | .9556                   | 11.18   | .....              | 25.25                   | .9018   |   | 27.93              |
| 16.75   | .9540                   | 11.64   | .....              | 25.50                   | .9003   |   | 28.42              |
| 17.00   | .9524                   | 12.10   | .....              | 25.75                   | .8989   |   | 28.91              |
| 17.25   | .9508                   | 12.56   | .....              | 26.00                   | .8974   |   | 29.40              |
| 17.50   | .9492                   | 13.02   | .....              | 26.25                   | .8960   |   | 29.89              |
| 17.75   | .9475                   | 13.49   | .....              | 26.50                   | .8946   |   | 30.38              |
| 18.00   | .9459                   | 13.96   | .....              | 26.75                   | .8931   |   | 30.87              |
| 18.25   | .9444                   | 14.43   | .....              | 27.00                   | .8917   |   | 31.36              |
| 18.50   | .9428                   | 14.90   | .....              | 27.25                   | .8903   |   | 31.85              |

| °Baumé. | Sp. Gr. | $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %NH <sub>3</sub> . | °Baumé. | Sp. Gr. | $\frac{60^{\circ}\text{F.}}{60^{\circ}\text{F.}}$ | %NH <sub>3</sub> . |
|---------|---------|---|--------------------|---------|---------|---|--------------------|
| 27.50   | .8889   |   | 32.34              | 28.50   | .8833   |   | 34.30              |
| 27.75   | .8875   |   | 32.83              | 28.75   | .8819   |   | 34.79              |
| 28.00   | .8861   |   | 33.32              | 29.00   | .8805   |   | 35.28              |
| 28.25   | .8847   |   | 33.81              |         |         |   |                    |

### ALLOWANCE FOR TEMPERATURE.

The coefficient of expansion for ammonia solutions, varying with the temperature, correction must be applied according to the following table:—

| Degrees<br>°Baumé. | Corrections to be<br>Added for Each<br>Degree Below 60° F. |        | Corrections to be Subtracted for<br>Each Degree Above 60° F. |        |        |         |
|--------------------|--|--------|--|--------|--------|---------|
|                    | 40° F.   | 50° F. | 70° F.   | 80° F. | 90° F. | 100° F. |
| Bé.                | Bé.  | Bé.    | Bé   | Bé     | Bé     | Bé.     |
| 14°                | .015°  | .017°  | .020°  | .022°  | .024°  | .026°   |
| 16°                | .021°  | .023°  | .026°  | .028°  | .030°  | .032°   |
| 18°                | .027°  | .029°  | .031°  | .033°  | .035°  | .037°   |
| 20°                | .033°  | .036°  | .037°  | .038°  | .040°  | .042°   |
| 22°                | .039°  | .042°  | .043°  | .045°  | .047°  |         |
| 26°                | .053°  | .057°  | .057°  | .059°  |        |         |

## OILS AND FATS.

### Examination of Oils and Fats.

1. *Specific Gravity.* This is determined by means of a pyknometer or Westphal balance, fats at 100°C. and oils at 15°C. A correction of  $\pm 0.00064$  is made for each degree Centigrade.

2. *Melting point.* A small quantity of the melted and filtered fat is introduced into a piece of capillary tubing, one end of which is sealed, and the melting point determined in the usual manner. An alternative method is to place a small piece of the fat on mercury contained in a crucible, and determine the temperature of the mercury at which the fat melts.

3. *Solidifying point of fatty acids (Titer test).* When a fat is allowed to solidify, the temperature frequently rises slightly during the short period in which the fat is actually changing from the liquid to the solid state owing to the latent heat being set free. In the case of solidification of fatty acids, the highest point of this rise in temperature is known as the Titer.

52 grm. of fat are saponified with 40 cc. of caustic soda solution (56° Tw.) and 50 cc. of alcohol, and evaporated until almost dry. The soap is dissolved in one litre of hot water, and the fatty acid liberated by the addition of 60 cc. of sulphuric acid (1:4 by volume). The whole is then boiled until the fatty acids form a perfectly clear layer on top. The acid liquor is run off, and the fatty acids washed free from mineral acid with hot water. The fatty acids are separated from the water, dried in a water-bath for an hour, transferred to a Titer-tube, and allowed to solidify, the temperature being taken by means of a thermometer graduated in fifths of a degree. When the temperature becomes constant, rises, and falls again, the highest point attained is the Titer of the fatty acids.

4. *Refractivity* is determined by means of the Abbé Refractometer.

5. *Water.* For a rapid test on neutral fats, 5 to 10 grm. are heated to 110°C. in a crucible, the fat being stirred with

a very small thermometer. Loss in weight at  $110^{\circ}$  is taken as water.

The test most frequently used is to heat 5 to 10 grm. of fat for one hour in an air-oven at  $95^{\circ}\text{C}$ .

The xylene method is more accurate. About 50 grams of fat are mixed with 50 cc. of xylene in a distillation flask. The flask is heated, and the distillate collected in a bulb-tube with a long constriction at the lower end, graduated in tenths of a cc. The first portion of the distillate contains all the water, and the distillation is continued until the B.Pt. of pure xylene is attained, and the condenser has been well washed with xylene vapour. On allowing to stand for 3 or 4 hours, all the water separates from the distillate, the volume is measured, and the percentage of water is calculated on the weight of fat used.

Acid fats are heated in a stream of dry carbon dioxide at  $105^{\circ}$  to  $110^{\circ}\text{C}$ ., and loss in weight is accepted as water. They may also be tested directly by the xylene method.

6. *Ash*. About 5 grm. of fat are burnt in a porcelain or platinum crucible, and heated until all the carbon has burnt off. The ash may be analysed by the usual method.

7. *Insoluble matter and dirt*. 20 grm. of the evenly mixed fat are dissolved in about 100 cc. of petroleum ether. The solution is filtered through a weighed filter-paper, which is washed free from fat with petroleum ether, when a drop of the filtrate leaves no grease-spot on paper. The filter-paper is then re-weighed. The ash is subtracted from the total insoluble to give the *organic insoluble matter*.

8. *Unsaponifiable* (e.g. mineral oil). 5 grm. fat are saponified with 25 cc. 2N alcoholic potash on the water-bath. The soap is dissolved in water, and the solution shaken with two amounts of 50 cc. each distilled ethyl ether in two separating funnels. The clear ether extract is withdrawn, washed with water, and evaporated in a weighed flask. The insoluble matter is also saponified with alcoholic potash in exceptional cases.

9. *Total fat*. The filtrate from (7) is evaporated and weighed, or 5 grm. fat are mixed with 4 to 6 times the amount of Calais sand dried at  $100^{\circ}\text{C}$ ., and extracted with ether or petroleum ether. The disadvantage of the former is that it is slightly soluble in water, whilst the latter cannot be entirely removed from the fat. It is usual, however, to estimate the total fat by difference of water, ash, and insoluble matter from 100%.

10. *Free mineral acid*. The fat is shaken with warm water, and the water tested with methyl orange and titrated if necessary.

11. *Calcium soaps*, generally found in bone-fat. The insoluble residue from the petroleum ether solution (7) is washed from the filter into a tube, and decomposed with hydrochloric acid. The fatty acids are extracted with ether and weighed; from this the total calcium soaps may be calculated.

## CONSTANTS OF OILS AND FATS.

1. The *Saponification value* is the number of milligrams of KOH required to saponify 1 gm. of the fat.

2.5 to 4 gm. of the fat are saponified with 50 cc. N/2 alcoholic potash (made by dissolving 30 gm. solid KOH in 1 litre of alcohol of Sp. Gr. 0.81, and, after one or two days, filtering through glass wool) on the water-bath under a reflux condenser for 30 minutes. Phenolphthalein is added and the solution titrated with N/2 hydrochloric acid. A blank test is carried out on another 50 cc. of the alcoholic potash, and the saponification value calculated from the figures so obtained.

In the case of dark-coloured fats, advantage is taken of the insolubility of the barium soap. 5 gm. of the fat are saponified with 50 cc. alcoholic potash, 50 cc. N/2 BaCl<sub>2</sub> solution and 300 cc. water added, and heated under a reflux condenser for 30 minutes. The baryta soap and foreign matter are precipitated, and if it is then impossible to titrate the solution directly, it is made up to 600 cc. with water, filtered through linen, and an aliquot portion titrated.

2. The *Iodine value* is the percentage of iodine with which the unsaturated acids of a fat will combine.

Hubl's method. 0.15 to 0.2 gm. of a drying oil, 0.3 to 0.4 gm. of a non-drying oil, or 0.8 to 1 gm. of a solid fat are dissolved in 15 cc. chloroform, and 25 to 50 cc. of Hübl's iodine solution (made by mixing solutions of 25 gm. iodine in 500 cc. 90 per cent. alcohol, and 30 gm. HgCl<sub>2</sub> in 500 cc. alcohol) added. After allowing to stand for 24 hours in a stoppered bottle out of contact with light, 15 to 20 cc. KI solution are added, to prevent precipitation of mercuric iodide, and the solution titrated with sodium thiosulphate solution (24 gm. per litre) until it is pale yellow. Water and starch solution are added, and the titration completed. The thiosulphate solution is standardised against the iodine solution, and also against a solution of 3.874 gm. K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> in 1 litre, of which 1 cc. corresponds to 0.01 gm. free iodine. (10 cc. 10 per cent. potassium iodide solution, 5 cc. concentrated hydrochloric acid, and 20 cc. potassium dichromate solution are allowed to stand for 15 minutes and then titrated with thiosulphate,

using starch solution as indicator.) From these values the Iodine value may be calculated.

Hanus method. 0.15 to 1.0 gm. of the fat, according to its nature (see Hubl's method), is weighed into a small glass tube, which is transferred to a 350 cc. bottle with a well-ground stopper. The oil is dissolved in 10 cc. chloroform, 20 cc. Hanus solution added, and the whole allowed to stand for one hour with occasional shaking. 20 cc. of a 10 per cent. solution of potassium iodide and 150 cc. water are added, and the iodine liberated titrated with N/10 sodium thiosulphate solution. A blank test on the chloroform and Hanus solution is performed at the same time. The iodine value is calculated from the difference between the amounts of thiosulphate solution required by the blank and the test.

The Hanus solution is prepared by dissolving 13.2 gm. iodine in 1,000 cc. glacial acetic acid, and adding 3 cc. bromine. The acetic acid used should not give a green colour when mixed with a few cc.'s of a solution of chromic acid in concentrated sulphuric acid.

Wijs' method. 0.15 to 1 gm. of the fat (see Hubl's method) is weighed off and introduced into a litre bottle provided with a ground-glass stopper. The fat is dissolved in 10 cc. of carbon tetrachloride, 25 cc. of the Wijs' solution added, and the mixture allowed to stand in the dark: half-an-hour for non-drying oils, one hour for semi-drying oils, or two hours for drying oils. If the deep brown colour of the solution disappears, a further 25 cc. of the Wijs' solution is added. After standing for the requisite amount of time, 15 to 20 cc. of a 10 per cent. solution of potassium iodide and 500 cc. of water are added. If a red precipitate of mercuric iodide is obtained at this point, further potassium iodide solution must be added. The free iodine is then titrated with standard thiosulphate. A blank is carried out to determine the exact strength of the Wijs' solution, and the iodine value is calculated upon the difference between blank and test as before.

Wijs' solution is prepared by dissolving 9.4 gm. of iodine trichloride and 7.2 gm. of iodine separately in glacial acetic acid on the water-bath, care being taken that no moisture is absorbed during the process of solution. The two solutions are poured into a litre flask, and made up to the mark with glacial acetic acid. The glacial acetic acid, and also the carbon tetrachloride used in the test, must be tested for oxidisable impurities by means of chromic acid and concentrated sulphuric acid; they should not change to a green colour even on prolonged standing.



A cheaper and more convenient laboratory method of preparing Wijs' solution consists in dissolving 13 grm. of iodine in a small amount of glacial acetic acid and determining exactly the iodine present by titration with standard thio-sulphate. Washed and dried chlorine gas is then passed into the solution until the titration with thiosulphate is exactly doubled. (A small quantity of the original solution may be held back for addition in case the passage of the chlorine has been continued too long.) A very pronounced change in colour takes place when the titration is doubled, and hence the point at which all the iodine is converted into iodine monochloride is easily ascertained.

3. The *Hehner value* is the percentage of water-insoluble fatty acids and unsaponifiable matter in a fat. 3 grm. of the fat are saponified with 50 cc. alcohol and 2 grm. KOH in a porcelain dish on the water-bath, the solution evaporated to dryness, and the residue dissolved in 100 cc. hot water. The insoluble fatty acids are liberated by addition of 5 cc. conc.  $\text{H}_2\text{SO}_4$ , melted, and transferred to a weighed filter. They are washed with hot water, solidified, dried and weighed. (Butter fat contains 87.5 per cent., and vegetable fat 95.5 per cent. insoluble fatty acids. If, for example, 91 per cent. insoluble fatty acids is found, the percentage of added fat (x) is found as follows:

$$95.5 - 87.5 = 8; 91 - 87.5 = 3.5; \text{ and } 8 : 3.5 = 100 : x.)$$

4. *Volatile fatty acids.* The Reichert-Meissl number is the number of cc. of N/10 alkali required for neutralisation of the volatile fatty acids distilled from 5 grm. of the fat.

5 grm. of the fat are gently warmed with 20 grm. glycerin and 2 cc. caustic soda (100 parts NaOH in 100 parts water). When the frothing has subsided, and the mixture becomes quite clear, the saponification is complete. The solution is cooled to  $90^\circ\text{C}.$ , and 90 grm. hot water, and 50 cc. dilute sulphuric acid (25 cc.  $\text{H}_2\text{SO}_4$  per litre) are added. The flask in which the experiment is carried out is connected by means of a bent bulb-tube to a condenser, 110 cc. are distilled over, filtered, and 100 cc. of the filtrate withdrawn by means of a pipette. This is titrated with N/10 alkali, using phenolphthalein as indicator. The number of cc. found is multiplied by 1.1, which gives the true Reichert-Meissl number.

5. *Maumené test* (Archbutt's modification). 50 grm. of the oil are placed in a 200 cc. beaker, and placed, together with a bottle of concentrated sulphuric acid, in a large vessel of water until both liquids have acquired the same temperature, which should be about  $20^\circ\text{C}.$  The beaker containing the oil is then removed, wiped on the outside, and transferred to a

cardboard box lined with cotton wool. A thermometer is immersed in the oil, the temperature noted, and 10 cc. of the concentrated sulphuric acid are withdrawn from the bottle by means of a pipette, and run into the oil, the time for emptying the pipette being one minute. The oil is stirred until no further rise in temperature takes place, when the rise in degrees Centigrade is taken as the Maumené number. The apparatus used must be a standard one, and the acid always of the same strength, so that the results obtained may be comparative.

## VARIABLES OF OILS AND FATS.

1. The *Acid value* is the number of milligrams of KOH required to neutralise the free acid in 1 grm. of a fat. 2 grm. of fat are dissolved in 50 cc. alcohol or ether-alcohol mixture, a few drops of phenolphthalein added, and titrated with N/2 caustic alkali. For oils containing very small amounts of free acid, 5 to 10 grm. are dissolved in ether or petroleum ether, an equal volume of alcohol added, and titrated with N/10 alkali.

The free acid may also be calculated as percentage of oleic acid in the original fat (1 cc. N. alkali = 0.282 grm. oleic acid).

2. The *Ester value* is the number of milligrams of KOH required to saponify the neutral esters in 1 grm. of fat, and is the difference between the saponification and acid values. From this the glycerin content may be ascertained, as in the saponification of neutral esters 1 grm. of caustic potash liberates 0.5476 grm. glycerin.

For dark-coloured fats, the free acids are neutralised with sodium carbonate (1.5 grm.  $\text{Na}_2\text{CO}_3$  in 50 cc. of 50 per cent. alcohol), 50 cc. N/2 alkali are added, and the saponification conducted on the water-bath as before. The baryta soap colouring matter, and carbonate are precipitated by means of 150 cc. of a 5 per cent.  $\text{BaCl}_2$  solution, and the clear solution titrated with oxalic acid.

3. The *Acetyl value* shows the amount of oxyacids present in the fat, represented by the number of milligrams of KOH necessary to saponify 1 grm. of the acetylated oil. 10 cc. of the oil are mixed with 10 cc. of acetic anhydride and 1 to 2 grm. of recently fused, anhydrous sodium acetate, and boiled on a sandbath for two hours under a reflux condenser. The mixture is cooled, water is added, and the mixture heated for half-an-hour. The acetylated oil is transferred to a separating funnel, washed with dilute caustic soda, and then with water

until neutral. The acetylated oil is dried over anhydrous sodium sulphate, and then about 2 grm. are saponified with alcoholic caustic potash as described under "Saponification value," the result being calculated in the same manner.

## ADULTERATION OF FATS.

The determination of the refractivity and the other constants gives an indication of the adulteration of fats. The following reactions serve to identify certain fats :

1. *Phytosterol*. 50 grm. fat are saponified with 95 cc. of 15 per cent. alcoholic potash on the water-bath. The powdered soap is extracted with ether in a separating funnel, the tap of which is packed with cotton wool. In about an hour the unsaponifiable matter, particularly phytosterol and cholesterol, passes into ether solution, which is separated and evaporated. The residue is saponified with 5 cc. alcoholic potash, and the soap extracted again with ether. The residue from the ether solution is extracted with hot alcohol. Cholesterol or phytosterol crystals (thin plates or clusters of needles) are deposited from the alcohol solution, and these are purified by repeated solution in ether, and recrystallisation from alcohol. The crystals are identified by examination in polarised light, or by the melting point of the acetate obtained as follows :

The crystals are heated in a thin glass vessel with 2 to 3 cc. acetic anhydride, and the ester produced dissolved in 25 cc. absolute alcohol. The crystals slowly precipitated from this solution are recrystallised, and the melting point ascertained. The true melting point is obtained by means of the usual formulæ. Melting point of cholesterol acetate is  $114.6^{\circ}$  (corr.). If the M.P. is over  $119^{\circ}$ , it corresponds to phytosterol, which is present only in vegetable fats.

2. *Detection of Vegetable oils in Animal fats*. 1 grm. of the molten, filtered fat (e.g. lard) is dissolved in 5 cc. chloroform, and shaken with 2 cc. phosphomolybdic acid solution (sodium salt +  $\text{HNO}_3$ ). In absence of vegetable oils the mixture is yellow; in their presence it is green, and the aqueous layer is light green, turned blue by ammonia. This is not quite reliable, as fish oils behave as vegetable oils.

3. *Detection of Cotton Seed Oil*. 2 cc. of oil are heated in a brine-bath with an equal volume of amyl alcohol and carbon disulphide in which 1 per cent. of sulphur is dissolved, when, in presence of cotton seed oil, a magenta coloration is obtained.

4. *Detection of Oil of Sesame.* To 0.1 cc. of a solution of 2 gm. furfural in 100 cc. alcohol, 5 cc. of molten fat (or 10 cc. oil) and 10 cc. hydrochloric acid (Sp. Gr. 1.19) are added, and the mixture shaken for half a minute, and allowed to settle. The bottom layer is coloured carmine in presence of Sesame oil.

5. *Detection of Arachis Oil.* Arachidic acid (M.P.  $75^{\circ}$ ) is separated from the fatty acids by recrystallisation from alcohol.

6. *Detection of Turpentine.* This is effected in the polarimeter, using an oil diluted with petroleum ether. In a 200 mm. tube it causes a dextro-rotation of about  $30^{\circ}$ . Animal and vegetable oils only give  $\pm 1^{\circ}$ .

7. *Detection of Resin.* (See Resin soaps, later.)

8. *Detection of Mineral Oil.* Fluorescence ("bloom") may be observed. The unsaponifiable matter (in pure fats 0.5 to 1.5 per cent.) is abnormally high.

9. *Detection of Fish oils.* About 1 gm. of the fatty acids of the oil is dissolved in 40 cc. of ether, 5 cc. of glacial acetic acid added, and the mixture cooled to  $0^{\circ}\text{C}$ . in ice. Bromine is then added until the red colour persists in the solution. The mixture is allowed to stand at  $0^{\circ}\text{C}$ . for about 15 minutes, when the formation of a white precipitate (the bromine addition compound of the unsaturated fatty acids) indicates the presence of fish oils. The test may be made quantitative if the precipitate is carefully filtered off through a tared Gooch crucible.

Hydrogenated fish oils may not give this reaction, as the fatty acids may have been saturated by the hydrogenating process.

### Soap Analysis.

1. *Water.* 5 to 8 gm. of the clean soap are dried at  $100^{\circ}$  to  $105^{\circ}\text{C}$ . until the weight becomes constant. Soaps containing a large amount of water, and which melt about  $100^{\circ}$  are mixed with pumice-stone or sand. The presence of liquid hydrocarbons causes incorrect values in the direct determination.

2. *Total fat*, including fatty and resin acids, neutral fat and unsaponifiable.

10 gm. soap are dissolved in hot water, and decomposed in a separating funnel with dilute sulphuric acid. The fatty acids are shaken with 100 cc. petroleum ether (B.P. below  $65^{\circ}\text{C}$ .), and the water layer is run off into a second separating

funnel and again extracted with 100 cc. petroleum ether. The extracts are distilled on a water-bath ( $70^{\circ}$ ) and the residue dried, for cocoanut and palm kernel fatty acids not over  $55^{\circ}$ , and for linseed oil fatty acids in a sulphuric acid dessicator.

Another method necessitates the use of a burette of 200 to 250 cc. capacity, rounded at the bottom, and closed at the top by means of a tap. 10 gm. of the soap are dissolved in 50 cc. of a mixture of methylated spirit and water (1 : 1), and transferred to the burette, which contains an excess of hydrochloric acid. The burette is filled to the 100 cc. mark with water, and the soap decomposed by vigorous shaking. The volume is made up to 200 cc. with ether, the whole shaken, and allowed to stand. An aliquot portion, say 25 cc., of the ether is withdrawn, evaporated, and the residue weighed.

A further method consists in dissolving 20 gm. of the soap in water in an evaporating basin, decomposing with 10 to 15 cc. hydrochloric acid, and boiling until the fatty acids, etc., form a clear layer on top. 6 gm. of beeswax (or a mixture of 3 parts beeswax and 1 part paraffin wax) are added, and allowed to melt and mix with the fatty acids. The whole is cooled, and the cake of wax transferred to a tared crucible, in which it is dried, and finally weighed. The weight of beeswax is subtracted, and the percentage of total fat calculated on the remainder.

3. *Unsaponifiable matter* is determined as for oils and fats. Cocoanut oil and palm kernel oil soaps are cleaned and dried, and then extracted directly with ether to extract the unsaponifiable matter.

4. *Free fatty acids.* 20 gm. soap are dissolved in 60 per cent. alcohol and titrated with N/10 alcoholic potash:

1 cc. N/10 alkali = 0.0282 gm. oleic acid.

5. *Unsaponified fat.* 6 to 8 gm. of the total fat from (2) are dissolved in 96 per cent. alcohol and made slightly alkaline with N/2 alkali, using phenolphthalein as indicator. This is extracted with ether, and the residue on evaporation is unsaponified fat *plus* unsaponifiable matter. This is saponified with an excess of alcoholic potash. On extracting again with ether the unsaponifiable matter is obtained, and is subtracted from the residue from the first extraction to give unsaponified fat.

6. *Resin.* For detection of resin acids, the total fat obtained from (2) is boiled with acetic anhydride. After cooling, one or two drops of sulphuric acid (Sp. Gr. 1.53) are added. A transitory magenta coloration shows the presence of resin acids. A similar reaction is shown by cholesterol (*e.g.* wool fat).



For determination, 2 to 3 grm. are mixed with 10 times the amount of absolute alcohol. After cooling, dry HCl gas is bubbled through the solution, until no more absorption takes place (about  $\frac{3}{4}$ -hour is necessary). After standing for one hour, it is diluted with 5 times the amount of water, and shaken in a separating funnel with 75 cc. ether. The ether layer (containing ethyl esters of the fatty acids + resin acids) is withdrawn, washed, 50 cc. alcohol added, and titrated with N/2 alkali.

1 cc. = 0.175 grm. resin acids.

7. *Total alkali.* 10 grm. of the soap are decomposed with 50 (or if necessary 100) cc. of N.  $\text{H}_2\text{SO}_4$  in an evaporating dish. The solution is boiled until the fatty acids are clear, when it is allowed to cool, and the aqueous layer titrated with alkali. If the fatty acids do not solidify, 15 grm. wax (preferably beeswax) or stearin are added before the solution is cooled.

8. *Free alkali.* 10 grm. of the soap are dissolved in 100 cc. absolute alcohol, and titrated with N/10 HCl, using phenolphthalein as indicator.

For determining small amounts of free alkali, the soap is dissolved in water, and precipitated hot with barium chloride solution (30 : 100), and the filtrate from the barium soap is titrated with N/10 acid.

9. *Combined alkali.* The alcohol insoluble from (8) is dissolved in water and titrated. Alternatively, carbon dioxide is passed through an alcoholic solution of 10 grm. of the soap, until all free alkali is converted into carbonate. The solution is filtered, the precipitate washed with hot alcohol, dissolved in water, and titrated with N/10 HCl, using methyl orange as indicator.

Silicate and borate are estimated as carbonate by this method.

10. *Glycerin.* 5 grm. soap are dissolved in hot water, and decomposed with sulphuric acid on the water-bath. The solution is then filtered through a wet filter-paper and precipitated with basic lead acetate. It is diluted to 250 cc., and the glycerin determined in an aliquot portion (see under "Glycerin").

11. *Water softening power.* 2.5 grm. of the soap are dissolved in a mixture of alcohol and water, and the solution made up to 250 cc. This solution is then run from a burette into 10 cc. of  $\text{X}_{10}$  Clark's hardness solution and 90 cc. of distilled water until the foam obtained by vigorous shaking shows no inclination to break after one minute. The reading (A) of the burette is then taken and the water softening

power ( $x$ ) calculated as percentage from the following formula:—

$$x = \frac{2800}{A}$$

The  $X_{10}$  Clark's hardness solution is made by dissolving 2.287 grm. of calcium carbonate in as small an amount of dilute hydrochloric acid as possible, boiling to expel carbon dioxide, neutralising with dilute ammonia, and making up to a litre with distilled water

## 12. Foreign matter.

(a) The alcohol insoluble is determined by extraction with 98 per cent. alcohol in a weighed and dried (at  $105^\circ$ ) filter thimble.

(b) Inorganic matter. About 5 grm. soap are carefully carbonised in a weighed platinum capsule. The carbonised residue is powdered, digested with water, and filtered through an acid-extracted filter. The residue is dried in the capsule, and burnt completely to ash. The filtrate is evaporated in the same capsule, and finally taken to dryness with addition of a small amount of ammonium nitrate, ignited, and weighed.

For estimation of silicate, the ash is decomposed with HCl and dried. It is then reheated with conc. HCl. It is taken up with hot dilute HCl, filtered, and the filter-paper burnt in a platinum capsule, which is ignited and weighed.

(c) Organic substances. The amount of alcohol-insoluble organic matter is the difference between (a) and (b).

Starch. The saponified fatty acids from 5 to 10 grms. soap are extracted with 60 to 80 cc. 2 per cent. alcoholic potash, in which starch is insoluble. The residue and filter are digested with 60 cc. 6 per cent. aqueous KOH; the liquor is made acid with acetic acid, diluted to 100 cc. in a measuring cylinder with water, and filtered through cotton wool. 25 or 50 cc. of the filtrate are taken, and to this are added 2 drops acetic acid and 30 or 60 cc. 96 per cent. alcohol. On standing, a precipitate is formed, which is filtered off through a weighed filter, washed with 50 per cent., and then with absolute alcohol, finally with ether, and then dried and weighed.

Dextrin. This is extracted from the alcohol-insoluble by means of cold water and precipitated by alcohol.

Sugar. This is determined by means of the inversion polarimeter, or by means of Fehling's solution.

Alcohol. This is determined by means of the pyknometer in the distillate from the acid solution produced by the decomposition of the soap solution with  $H_2SO_4$ .



Liquid hydrocarbons and ethereal oils are distilled from a solution of 30 to 40 grm. of soap in 150 cc. water, decomposed with dilute  $H_2SO_4$ , and are collected in a calibrated burette.

(d) Oxygen agents (Sodium peroxide, perborate percarbonate, persulphate).

Detection: 2 grm. of the substance are shaken successively with water, dilute sulphuric acid, and 2 cc. of chloroform. Hydrogen peroxide may be detected in the aqueous layer by the chromic acid or titanous acid test.

The method of determining the oxygen by means of N/10 permanganate is stated to be incorrect by Bosshard and Zwicky, who use the gasimetric method, liberating the available oxygen by means of manganese dioxide. The most convenient is the method suggested by Farrar, in which ferrous ammonium sulphate is oxidised, and the ferric salt formed determined by titration with titanous chloride.

## Glycerin.

### I. Chemically Pure Glycerin

(a) *Specific Gravity* should be 1.24 to 1.26.

(b) *Colour* in a tintometer.

(c) *Ash* should be practically nil.

(d) *Impurities* usually tested for are sugar (by Fehling's solution), arsenic (by zinc, hydrochloric acid and mercuric chloride paper), chloride, sulphate, heavy metals (with hydrogen sulphide), butyric acid (by alcohol and sulphuric acid), and organic matter (by strong sulphuric acid).

### II. Dynamite Glycerin.

(a) This should be free from chloride, sulphate, calcium, magnesium, aluminium, and arsenic. 1 cc. should give no opalescence when mixed with 2 cc. water and 2 drops silver nitrate solution.

(b) *Specific gravity* at  $15^\circ C$ . should be 1.261 to 1.263.

(c) It should contain no free acid nor any quantity of reducing matter. Total insoluble should be very low. No turbidity should be caused by higher fatty acids, on addition of an equal volume of hydrochloric acid to 1 part glycerin in 2 parts water. There should be no precipitation of silver on addition of 3 drops of 10% silver nitrate. The total insoluble matter, when 5 grm. of the glycerin are heated to  $160^\circ$  to  $180^\circ C$ . until constant in weight, should not be above 0.25%.

(d) The product of nitration must be very pale, and separate easily.

About 20 gramm. of glycerin is run from a burette into a weighed beaker, and its weight determined. A water cooled beaker, containing 150 gramm. "mixed acid" (1 part commercial  $\text{HNO}_3$  of Sp. Gr. 1.5, and 2 parts  $\text{H}_2\text{SO}_4$  of Sp. Gr. 1.845) is brought under the burette, and glycerin is carefully run into this, stirring with a thermometer. The temperature must not rise above  $25^\circ\text{C}$ ., and fresh glycerin must only be run in when the temperature has fallen to 12 or  $13^\circ\text{C}$ . When an amount of glycerin, equal in volume to the quantity first withdrawn from the burette and weighed, has been run into the acid, the contents of the beaker are poured into a measuring cylinder, and the separation observed.

The number of cc. of the upper layer, multiplied by the specific gravity of nitroglycerin (1.6009 at  $15^\circ$ ) gives the weight of nitroglycerin, which should not be under 200 per cent. of original glycerin used (usual figure 207–210 per cent.). The difference between this and the theoretical 246.7 per cent. shows the nitroglycerin dissolved in the "mixed acid."

### III. *Crude Glycerin.*

(International Standard Methods, 1911.)

(a) *Free caustic alkali.* 20 gramm. sample are diluted to 100 cc., together with an excess of neutral barium chloride solution and 1 cc. phenolphthalein solution. The precipitate is allowed to settle and 50 cc. of the clear liquid titrated with normal acid. Free caustic alkali is calculated as  $\text{Na}_2\text{O}$ .

(b) *Ash and total alkalinity.* 2 to 5 gramm. sample are thoroughly charred in a platinum dish over a very small flame; the mass is extracted with hot water, filtered, and the residue ignited in the dish. The filtrate and washings are then returned to the dish, evaporated, and ignited without fusion. The ash is weighed, dissolved, and titrated with normal acid for total alkalinity, calculated as  $\text{Na}_2\text{O}$ .

(c) *Alkali present as carbonate.* 10 gramm. sample are diluted with 50 cc. of distilled water and sufficient normal acid to neutralise the alkalinity found in (b). The solution is boiled under a reflux for 15 to 20 min., the condenser tube washed down into the flask, and the solution and washings titrated with normal caustic soda, using phenolphthalein as indicator. This figure is calculated to  $\text{Na}_2\text{O}$ , from which is subtracted that found in (a), the difference being  $\text{Na}_2\text{O}$  present as carbonate.

(d) *Alkali combined with organic acids.* The sum of the percentages of  $\text{Na}_2\text{O}$  found in (a) and (c) deducted from that found in (e) represents the  $\text{Na}_2\text{O}$  or other alkali combined with organic acids.

(e) *Acidity.* 10 grm. sample diluted with 50 cc. distilled water are titrated with normal caustic soda, using phenolphthalein as indicator. The result is expressed in terms of  $\text{Na}_2\text{O}$  to neutralise 100 grm.

(f) *Total residue at 160°C.* 10 grm. sample, together with sufficient normal hydrochloric acid or sodium carbonate to cause the glycerin to have an alkalinity not exceeding 0.2% sodium carbonate, are made up to 100 cc., and 10 cc. measured into a tared flat-bottomed dish. This is placed on top of the air oven, until most of the water has evaporated. The dish is then transferred to the interior of the oven, the door of which is left open so that most of the glycerin is evaporated at 130°–140°C. The dish is then allowed to cool, and the residue taken up with 0.5–1.0 cc. water. This is evaporated on top of the oven, and the dish heated in the oven at 160°C. for one hour, cooled and weighed. The process of treating with water, evaporating, heating for one hour, cooling and weighing, is repeated until a constant loss of 1 to 1.5 mgrm. per hour is obtained. The weight is corrected for the amount of hydrochloric acid or sodium carbonate added, and the result multiplied by 100 to give the percentage of total residue at 160°C.

(g) *Organic residue at 160°C.* The ash is subtracted from the result found in (f), the difference being expressed as organic residue at 160°C.

(h) *Moisture.* 1 to 1.5 grm. sample are dried on a weighed quantity of pure bulky asbestos in a vacuum dessicator containing sulphuric acid.

(i) *Glycerin.*

(i) *Acetin method.* 1.25 to 1.5 grm. sample are weighed into a 120 cc. flask, connected to a reflux condenser by means of a ground glass joint. The glycerin is then boiled for one hour with 7.5 cc. of pure acetic anhydride and 3 grm. of pure, recently fused sodium acetate. This mass is allowed to cool, 50 cc. water added down the condenser, and warmed to 80°C. until solution is complete. The solution is filtered into a litre flask and the acetylating flask and filter paper well washed. 2 cc. of 0.5% phenolphthalein solution are added and the solution exactly neutralised. 50 cc. normal caustic soda are added, and the solution gently boiled under a reflux air condenser for 15 mins. It is then quickly cooled and titrated with normal acid. From the amount of caustic soda used the percentage of glycerin may be calculated, after making a correction for a blank test done on 7.5 cc. of acetic anhydride and 3 grm. of sodium acetate.

1 cc. N. NaOH = 0.03069 grm. glycerin.

A further correction may be made if the organic residue at  $160^{\circ}\text{C}$ . is high, by acetylising the organic residue and proceeding as above. The result is calculated to glycerin and subtracted from the above.

(ii) Dichromate process. 20 grm. glycerin are diluted to 250 cc., 20 cc. taken, and a small amount of silver carbonate (freshly precipitated from 140 cc. of 0.5% silver sulphate solution by means of about 4.9 cc. normal sodium carbonate solution) added. The solution is allowed to stand, with occasional agitation for 10 mins., when a slight excess of basic lead acetate solution is added. The mixture is allowed to stand a few moments, and is made up to 100 cc., an extra 0.15 cc. being allowed for the volume of the precipitate. The whole is then thoroughly mixed and filtered. 25 cc. of the clear filtrate are taken, 12 drops of pure sulphuric acid (1:4), and then 3.7282 grm. pure powdered potassium dichromate added. This is rinsed down with 25 cc. water, the dichromate is allowed to dissolve, and 50 cc. of sulphuric acid (1:1) added. The solution is kept in a boiling water-bath for 2 hours, a weighed excess of ferrous ammonium sulphate added, and the excess titrated with dilute potassium dichromate solution, using potassium ferricyanide as outside indicator. The glycerin is calculated from the amount of dichromate reduced.

1 grm. glycerin = 7.4564 grm. dichromate.

1 grm. dichromate = 0.13411 grm. glycerin.

#### IV. *Soap Lyes.*

The glycerin in soap lyes may be estimated by boiling down a quantity of the lye and carrying out an acetin test on the residue, or by a dichromate test on the lye itself. The former is the more accurate method, but the latter is more rapid and more suitable for works practice.

5 cc. of the soap lye are neutralised with semi-normal hydrochloric acid, and the soap precipitated by basic lead acetate (the necessary quantities may be determined on a separate quantity of 5 cc.). The solution is then made up to 250 cc., allowing 0.25 cc. for the volume of the precipitate. The mixture is thoroughly shaken, and then filtered. 50 cc. of the clear filtrate are taken, a few drops of 1:4 sulphuric acid added to precipitate any slight excess of lead, and then an excess of fairly strong potassium dichromate and 50 cc. of sulphuric acid (1:1) added. The solution is heated in a boiling water bath for two hours and then titrated back with ferrous ammonium sulphate solution. The percentage of glycerin is calculated from the amount of dichromate reduced, as for pure glycerin determinations.

# OILS, FATS, AND WAXES.

| Name and Source.                                | Sp. Gr. at 15.5°     |                         | Refractive index.        |                            | Solidifying Pt., °C.<br>for oils, &c. | Titer test<br>on<br>fatty acids<br>°C. | Melting Pt. °C. |                 | % Insoluble<br>fatty acids<br>and unsaponi-<br>fiable matter. |
|---|----------------------|-------------------------|--------------------------|----------------------------|---------------------------------------|--|-----------------|-----------------|---|
|   | Oils, &c.            | Fatty acids.            | Oils at<br>15°C., &c.    | Fatty<br>acids at<br>60°C. |                                       |  | Oils, &c.       | Fatty<br>acids. |   |
| 1 Almond oil<br><i>Prunus amygdalus</i>         | 0.9178<br>—0.9183    | ...                     | 1.4728                   | 1.4461                     | —10 to<br>—21                         | 9.5—10.1                               | ...             | 13—14           | 96.2  |
| 2 Apricot kernel oil                            | 0.9172<br>—0.920     | 0.9195                  | 1.4712<br>(20°)          | ...                        | —20                                   | ...                                    | ...             | 2.3—4.5         | 95.40   |
| 3 Arachis oil<br><i>Arachis hypogæa</i>         | 0.91795              | 0.8460 (99°)            | 1.4731                   | 1.4461                     | 0 to +2                               | 23.1—32                                | ...             | 31—32           | 94.8—95.3   |
| 4 Beechnut oil<br><i>Fagus sylvatica</i>        | 0.9205<br>—0.9225    | ...                     | ...                      | ...                        | —17                                   | 17                                     | ...             | 23—24           | 95.16   |
| 5 Ben oil<br><i>Moringa pterygosperma</i>       | 0.912—0.920          | ...                     | ...                      | ...                        | 8.8                                   | 37.2—37.8                              | ...             | ...             | ...   |
| 6 Bee tallow                                    | 0.943—0.952<br>(15°) | 0.8698 (100°)           | 1.4510<br>(60°)          | 1.4375                     | 35—27                                 | 43.5—44.5                              | 43—47.6         | 43—46           | 95.4—96   |
| 7 Beeswax<br><i>Apis mellifica</i>              | 0.962—0.975<br>(15°) | ...                     | ...                      | 1.4398<br>—1.4451<br>(75°) | 60.2—62.5                             | ...                                    | 62.5—63.6       | 67.2            | ...   |
| 8 Bone fat                                      | 0.914—0.916          | ...                     | ...                      | ...                        | 15—17                                 | 28                                     | 21—22           | 30              | 90—97   |
| 9 Butter fat                                    | 0.936—0.940<br>(15°) | 0.907—0.914<br>(37.75°) | 1.459<br>—1.462<br>(25°) | 1.437<br>—1.439            | 19.1—24.5                             | 35.8—38                                | 28.4—33.3       | 38—43           | 86.45—89.8  |
| 10 Cacao butter<br><i>Theobroma cacao</i>       | 0.964—0.976          | 0.91357                 | 1.4496(60°)              | 1.422                      | 23—26                                 | 48.3—49.6                              | 28.5—33.6       | 48—52           | 94.59   |
| 11 Candellila wax<br><i>Pedilanthus pavonis</i> | 0.936—0.993<br>(15°) | ...                     | 1.4555<br>(71.5°)        | ...                        | 63.8—68                               | ...                                    | 66—68.4         | ...             | ...   |
| 12 Carnatba wax<br><i>Corypha cerifera</i>      | 0.990—0.999<br>(15°) | ...                     | ...                      | ...                        | 80—87                                 | ...                                    | 83—86           | ...             | ...   |
| 13 Castor oil<br><i>Ricinus communis</i>        | 0.9591               | 0.9509                  | 1.4795<br>—1.4803        | 1.4546                     | —10 to<br>—12                         | 3                                      | ...             | 13              | ...   |

| Unsaponifiable matter. | Saponification value mgrams. KOH for oil, &c. | Neutralisation value of fatty acids. | Iodine value %      |                     | Mau-<br>mené's<br>Test,<br>0°C. | Reichert-<br>Meissl<br>value<br>N KOH.<br>cc. 10 | Mean<br>mol.-wt.<br>of fatty<br>acids. | Acid value.    | Other data.  |
|------------------------|---|--------------------------------------|---------------------|---------------------|---------------------------------|--|--|----------------|--|
|                        |   |                                      | Oils, &c.           | Fatty<br>acids.     |                                 |  |  |                |  |
| 1                      | ...   | 204                                  | 93.0—<br>100.2      | 93.5—96.5           | 51—53                           | ...  | 275                                    | 0.7—5.6        | White elaidin.   |
| 2                      | ...   | 197                                  | 101—108.7           | 102.6<br>—103.8     | 42.5                            | ...  | 288.6                                  | 0.64           |  |
| 3                      | 0.54—0.94                                     | 201.6                                | 83.3—105.9          | 95.5—96.9           | 46—51                           | ...  | 281.8                                  | 1.2—32         |  |
| 4                      | ...   | ...                                  | 111.2<br>—120.1     | 114                 | 63—65                           | ...  | ...                                    | ...            |  |
| 5                      | 1.67—2.69                                     | ...                                  | 72.88 &<br>110—112  | ...                 | ...                             | ...  | ...                                    | ...            |  |
| 6                      | ...   | 197.2<br>—201.6                      | 35.4—47.5<br>7.9—11 | 25.9—32.8<br>& 41.3 | ...                             | 0.25   | 270—285                                | 3.5—50         |  |
| 7                      | 52.4—55.6                                     | ...                                  | ...                 | ...                 | ...                             | 0.34—0.54  | ...                                    | 17—22          | Acetyl value 15.24.  |
| 8                      | 0.5—1.8                                       | 200                                  | 46.3—49.6           | 55.7—57.4           | ...                             | ...  | 275                                    | 210—211.4      | Ash 1.25—2.40%.<br>Water 11.6%. Heat of<br>Bromination 6.6—7.0 & 9.5 |
| 9                      | 0.31—0.42                                     | 210—220                              | 25.7—37.9           | 28—31               | ...                             | 20.63<br>—33.15                                  | 263                                    | 0.4—35         |  |
| 10                     | 1.75—3.08                                     | 190                                  | 34.3—37.5           | 32.6—39.1           | ...                             | 0.3—0.5  | 295                                    | 1—2.8          |  |
| 11                     | 65—77   | ...                                  | 14—20               | ...                 | ...                             | ...  | ...                                    | 12.4<br>—21.13 | Sol. in turpentine, chloro-<br>form, and carbon tetra-<br>chloride.  |
| 12                     | 54.8—55                                       | ...                                  | 13.2—13.5           | ...                 | ...                             | ...  | ...                                    | 2—7            |  |
| 13                     | 0.30—0.57                                     | ...                                  | 81.4—90.6           | 86.6—88.3           | 46—47                           | 1.1  | 295                                    | 0.3—4          | Acetyl value 150 Opt.<br>Rot. 200 mm. 7.5° to 10°.                   |



# OILS, FATS, AND WAXES—continued.

| Name and Source.   | Sp. Gr. at 15.5°                         |                                     | Refractive index.  |                      | Solidifying Pt. °C. for oils, &c. | Titer test on fatty acids °C. | Melting Pt. °C. |              | % Insoluble fatty acids and unsaponifiable matter. |
|--|--|-------------------------------------|--------------------|----------------------|-----------------------------------|-------------------------------|-----------------|--------------|--|
|  | Oils, &c.                                | Fatty acids.                        | Oils at 15°C., &c. | Fatty acids at 60°C. |                                   |                               | Oils, &c.       | Fatty acids. |  |
| 14 Chaulmogra oil<br><i>Taraktogenos Kurzii</i>                            | 0.951—0.952 (25°)                        | ...                                 | 1.4777 (25°)       | ...                  | ...                               | 39.6                          | ...             | 44—45        | ...  |
| 15 Chinese Tung oil<br><i>Aleurites cordata</i>                            | 0.940—0.943                              | ...                                 | 1.521—1.523        | ...                  | 2—3                               | 37.1—37.2                     | ...             | 40.3—43.8    | 95.0   |
| 16 Chinese vegetable tallow<br><i>Stillingia sebifera</i>                  | 0.890 & 0.915—0.918 (15°)<br>0.970 (15°) | ...                                 | ...                | ...                  | 24.2—35                           | 52.1—53.5 & 40—48             | 43—46           | 53—56.9      | 93.45—95.7   |
| 17 Chinese wax (or insect wax)<br><i>Coccus ceriferus</i>                  | ...                                      | ...                                 | ...                | ...                  | 80.5—81                           | ...                           | 80.5—83         | 92.2         | 51.54  |
| 18 Clover oil<br><i>Trifolium</i>  | ...                                      | ...                                 | ...                | ...                  | ...                               | ...                           | ...             | ...          | R=red 93.62<br>W=white 93.24<br>88.6—90.5          |
| 19 Cocoa nut oil<br><i>Cocos nucifera</i>                                  | 0.9259                                   | 0.8354 (98—99°) (water 15.5=1)      | 1.441 (60°)        | 1.4295               | 14—23                             | 21.2—25.2                     | 23.5—26.4       | 24—27        | ...  |
| 20 Cod liver oil<br><i>Gadus morrhua</i>                                   | 0.9224—0.930                             | ...                                 | 1.4800—1.4852      | ...                  | 0 to —10                          | 13.3—24.3                     | ...             | ...          | 95.3—96.5  |
| 21 Corn oil, see Maize oil.  |  |                                     |                    |                      |                                   |                               |                 |              |  |
| 22 Cotton seed oil<br><i>Gossypium herbaceum</i>                           | 0.9250                                   | 0.92055—0.9219 (15.5°) <sub>4</sub> | 1.4743—1.4752      | 1.4460               | 3—4, below 12° stearine separates | 33.3—37.6                     | ...             | 34—38        | 95.96  |
| 23 Cotton seed wax<br>or Cotton seed stearin<br><i>Gossypium herbaceum</i> | 0.91884 (15°)                            | ...                                 | ...                | ...                  | 16—22                             | 34.9—40.8                     | 26—40           | 27—30        | 95.5—96.3  |
| 24 Croton oil<br><i>Croton Tiglium</i>                                     | 0.9375—0.9428                            | ...                                 | 1.4781 (26°)       | ...                  | —7                                | 18.6—19                       | ...             | ...          | 88.9—89.1  |



| Unsaponifiable matter.  | Saponification value mgrms. KOH for oil, &c. | Neutralisation value of fatty acids. | Iodine value %                                |                 | Mau-<br>mené's<br>Test,<br>0°C. | Reichert-<br>Meissl<br>value<br>cc. $\frac{N}{10}$ KOH. | Mean<br>mol.-wt.<br>of fatty<br>acids. | Acid value.        | Other data.  |
|-------------------------|--|--------------------------------------|---|-----------------|---------------------------------|---|--|--------------------|--|
|                         |  |                                      | Oils, &c.                                     | Fatty<br>acids. |                                 |   |  |                    |  |
| 14 ...                  | 200.3—213                                    | 215                                  | 103.2<br>—104.4                               | 103.2           | ...                             | ...   | ...                                    | 9.5—56             | Sp. Rot. $[\alpha]_{15}^{\circ}$ 52 to 51.3.         |
| 15 0.44                 | 190—197                                      | 188.8                                | 159—176.2<br>(Hubl), up<br>to 210<br>(Hanus). | 145.4<br>—159.4 | ...                             | ...   | ...                                    | 0—12               | Polymersed to jelly at 250°.                         |
| 16 ...                  | 200.3<br>—205.7                              | 202—208.5<br>32.1—32.3<br>& 28—37    |   | 30—55           | ...                             | 0.69  | ...                                    | 2.2—14.2           |  |
| 17 ...                  | 80.5—93                                      | ...                                  | 1.4   | ...             | ...                             | ...   | ...                                    | 1.4—1.5            | Alcohols 49.5%.                                      |
| 18 For R. =<br>For W. = | 189.9<br>189.5                               | 198.1<br>197.6                       | 124.3<br>119.7                                | 126.2<br>122.2  | ...                             | 3.3<br>3.5  | 283.2<br>283.8                         | ...                |  |
| 19 0.179<br>—0.297      | 251—268.4                                    | 258                                  | 8—10  | 8.39—9.3        | ...                             | 6.55—8.0  | 196—204                                | 5—50               |  |
| 20 0.54—7.83            | 179—193.4                                    | 204.4<br>—207                        | 135<br>—172.6                                 | 164—171         | 100.2<br>—116                   | 0.4—0.76<br>(Reichert)                                  | ...                                    | 0.25—3             | Sp. temperature reaction<br>243—272.                 |
| 21 22 0.73—1.64         | 191—193.8                                    | 201.6<br>—203.9                      | 101—120                                       | 105—115         | 75—76 &<br>80—90                | ...   | 275                                    | Below 2<br>(best)  | Heat of bromination 19.4,<br>Sp. T. reaction 169—170 |
| 23 ...                  | 195<br>210.3—                                | ...                                  | 90—103<br>101.7                               | 94<br>111.2     | ...                             | ...   | ...                                    | 19—32<br>27.3      |  |
| 24 0.22                 | —215.6                                       | 201                                  | —109.1  | —111.8          | ...                             | 12.1—13.6   | ...                                    | (expressed<br>oil) |  |

# OILS, FATS, AND WAXES—continued.

| Name and Source.  | Sp. Gr. at 15°                    |             | Refractive index.     |                      | Solidifying Pt. °C. for oils, &c. fatty acids at 60°C. | Titer test on fatty acids °C. | Melting Pt. °C.  |              | % Insoluble fatty acids and unsaponifiable matter. |
|---|-----------------------------------|-------------|-----------------------|----------------------|--|-------------------------------|------------------|--------------|--|
|   | Oils, &c.                         | Fatty acids | Oils at 15°C., &c.    | Fatty acids at 60°C. |  |                               | Oils, &c.        | Fatty acids. |  |
| 25 Curkas oil<br>or Purging nut oil<br><i>Jatropha curcas</i> | 0·9204                            | ...         | 1·4681—<br>1·487(25°) | ...                  | —8   | 28·6                          | —4               | 24—26        | 95·5   |
| 26 Ceresin<br><i>Ozokerite paraffin</i>                       | 0·9170 (20°)<br>0·918—0·922 (15°) | ...         | ...                   | ...                  | 61—63  | ...                           | 64—65<br>& 61—78 | ...          | ...  |
| 27 Dika fat or oil<br><i>Irvingia gabonensis</i>              | 0·863 (100°, water at 15°=1)      | ...         | 1·4505 (50°)          | 1·4357 (50°)         | 27·2—29·4 & 39·2—39·9                                  | 31·8—38·1                     | 38·9—41·3        | 40·8         | 91·38  |
| 28 Dolphin oil (body)<br><i>Delphinus globiceps</i>           | 0·9266 (15°)                      | ...         | 1·4708                | ...                  | 5 to—3 deposits spermaceti.                            | ...                           | ...              | ...          | ...  |
| 29 Earth nut oil, see Arachis oil.                            | 0·922                             | 0·9257(15°) | ...                   | ...                  | 18—20  | 31—34                         | 27·5—34          | 36·6—41      | 92·4—95·88   |
| 30 Goose fat<br><i>Anser cinereus</i>                         | —0·9300(15°)                      | ...         | ...                   | ...                  | —11 to —17   | 18—20                         | ...              | 23—26        | 92·13—97·6   |
| 31 Grape seed oil<br><i>Vitis vinifera</i>                    | 0·9202<br>—0·9561                 | ...         | 1·4713 (25°)          | ...                  | ...  | ...                           | ...              | ...          | ...  |
| 32 Gynocardia oil<br><i>Gynocardia odorata</i>                | 0·925—0·927 (25°)                 | ...         | ...                   | ...                  | Thickens at —15 and solidifies at —27                  | 15·6—16·6                     | ...              | 17—19        | ...  |
| 33 Hemp seed oil<br><i>Cannabis sativa</i>                    | 0·925<br>—0·931 (15°)             | ...         | 1·447<br>—1·496       | ...                  | ...  | ...                           | ...              | ...          | ...  |
| 34 Herring oil<br><i>Clupea harengus</i>                      | 0·9202<br>—0·9391 (15°)           | ...         | ...                   | ...                  | 42—47  | ...                           | ...              | 30—31·5      | 95·64  |
| 35 Horse fat<br><i>Equus caballus</i>                         | 0·916—0·922                       | ...         | ...                   | ...                  | ...  | 33·6—33·7                     | 41·8—43·2        | 37·5—39·5    | 96—97·8  |



# OILS, FATS, AND WAXES—continued.

| Name and Source  | Sp. Gr. at 15.5°      |                                | Refractive index.          |                      | Solidifying Pt. °C. for oils, &c. fatty acids | Titer test on fatty acids °C. | Melting Pt. °C. |               | % Insoluble fatty acids and unsaponifiable matter. |
|--|-----------------------|--------------------------------|----------------------------|----------------------|---|-------------------------------|-----------------|---------------|--|
|  | Oils, &c.             | Fatty acids.                   | Oils at 15°C., &c.         | Fatty acids at 60°C. |   |                               | Oils, &c.       | Fatty acids.  |  |
| 36 Japanese fish oil<br><i>Clupanodon melanosticta</i>       | 0.9316<br>—0.9347     | ...                            | 1.4802<br>—1.4808<br>(20°) | ...                  | ...   | 28.2                          | 20—22           | 35.4<br>—36.2 | 9.5—95.82  |
| 37 Japanese Tung oil<br><i>Elaeococca vernicia</i>           | 0.933<br>—0.9400      | ...                            | 1.5034<br>—1.5186<br>(25°) | ...                  | ...   | 33.2                          | ...             | 40.3          |  |
| 38 Japan wax<br><i>Rhus succedanea</i>                       | 0.975 (15°)           | 0.848 (98°—99°) (water 15.5=1) | ...                        | ...                  | 48.5<br>—50.8                                 | 58.8<br>—59.4                 | 50.4<br>—53.4   | 54—62         | 89.8—90.66   |
| Insect wax, see Chinese wax.                                 |                       |                                |                            |                      |   |                               |                 |               |  |
| 39 Illipé butter<br><i>Bassia longifolia</i>                 | ...                   | ...                            | ...                        | ...                  | 36  | 39.7—40.3                     | 42              | 45            | 94—94.76   |
| 40 Kapok oil<br><i>Bombax Ceila</i> and<br><i>peniandrum</i> | 0.9215 (15°)          | 0.9162 (18°)                   | ...                        | ...                  | 29.6  | 26.9—32                       | ...             | 29—34.2       | 94.9—95.66   |
| 41 Lard oil<br><i>Sus scrofa</i>                             | 0.915                 | ...                            | 1.4694                     | ...                  | ...   | ...                           | ...             | 35            | ...  |
| 42 Lard<br><i>Sus scrofa</i>                                 | 0.934<br>—0.938(15°)  | 0.837—0.840                    | 1.4539(60°)                | 1.4395               | 27.1—29.9                                     | 36.0                          | 81—48.9         | 43—47         | 95.8   |
| 43 Laurel oil<br><i>Laurus nobilis</i>                       | 0.9317<br>—0.953(15°) | ...                            | ...                        | ...                  | 24—25   | 14.3—15.1                     | 32—36           | ...           | 83.5—86.8  |
| 44 Linseed oil<br><i>Linum usitatissimum</i>                 | 0.9316<br>—0.9410     | 0.9233                         | 1.4835                     | 1.4546               | —25 deposits<br>stearine                      | 19—20.6                       | —16 to<br>—20   | 17—24         | 95.5   |
| 45 Maize oil<br><i>Zea Mays</i>                              | 0.9213<br>—0.9274     | 0.8529(100°)                   | 1.4768<br>(15.5°)          | ...                  | —10 to<br>—15                                 | 19                            | ...             | 18—21.6       | 93.57—95.7   |

| Unsaponifiable matter. | Saponification value<br>ingrms.<br>KOH for<br>oil, &c. | Neutralisation value<br>of fatty<br>acids. | Iodine value %   |                 | Mau-<br>mené's<br>Test,<br>0°C. | Reichert-<br>Meissl<br>value<br>cc. $\frac{N}{10}$ KOH. | Mean<br>mol.-wt.<br>of fatty<br>acids. | Acid value. | Other data.                          |
|------------------------|--|--|--|-----------------|---------------------------------|---|--|-------------|--------------------------------------|
|                        |  |  | Oils, &c.  | Fatty<br>acids. |                                 |   |  |             |                                      |
| 36 0.48-2.6            | 189.8<br>—196.2  | 180-189.1                                  | 180.6—<br>187.3<br>121.5<br>171 for<br>commer-<br>cial oils<br>149-158 | ...             | ...                             | ...   | 281-296                                | 10.8-34.5   | Ether insoluble<br>44.2-47.1%.       |
| 37 ...                 | 193.4—<br>196.3  | ...  | ...  | ...             | ...                             | ...   | 262-263                                | ...         | Heat of bromination 23.1—<br>24.7°C. |
| 38 1.1-1.63            | 220-237.5  | ...  | 4.9-15.1   | ...             | ...                             | ...   | 257.6                                  | 7-33        | Acetyl value 27-31.2.                |
| 39 ...                 | 187.4<br>—188.5  | 192.1                                      | 50.1-64  | 59.5            | ...                             | 1.35  | 291.9                                  | ...         |                                      |
| 40 ...                 | 189.2-205  | 190-202.7                                  | 118-129  | 108 & 122       | 95                              | ...   | 293                                    | 1.7-20.6    |                                      |
| 41 ...                 | 189.9-193  | ...  | 67-88  | ...             | 47                              | 0-0.21  | ...                                    | 1-2         |                                      |
| 42 0.23                | 195.2<br>—196.6  | 201.8<br>—203.6                            | 53-76.9  | 64.2            | 24-27.5                         | 0.49-0.77   | 278                                    | 0.54-1.28   |                                      |
| 43 ...                 | 197.5<br>—200.9  | ...  | 66-82.3  | 81.6-82.0       | 115.6                           | 3.2-5.4   | ...                                    | ...         |                                      |
| 44 0.42-1.1            | 190.2<br>—195.2  | 196-198.8                                  | 170-201  | 179-209.8       | 103-145                         | ...   | 283                                    | 0.8-8.4     | Sp. temper. reaction 320—<br>349.    |
| 45 1.35-2.86           | 189.7<br>—122.6  | 198.4                                      | 121-130.8  | 113-125         | 79-86                           | ...   | ...                                    | 1.7-20.6    |                                      |

# OILS, FATS, AND WAXES—continued

| Name and Source.                                    | Sp. Gr. at 15.5°   |  | Refractive index.       |                            | Solidifying<br>Pt. °C.<br>for oils, &c.<br>fatty acids | Titer test<br>on<br>fatty acids<br>°C. | Melting Pt. °C. |                  | % Insoluble<br>fatty acids<br>and unsaponi-<br>fiable matter. |
|---|--|--|-------------------------|----------------------------|--|--|-----------------|------------------|---|
|   | Oils, &c.  | Fatty acids.   | Oils at<br>15°C., &c.   | Fatty<br>acids at<br>60°C. |  |  | Oils, &c.       | Fatty<br>acids.  |   |
| 46 Menhaden oil<br><i>Alosa menhaden</i>            | 0.926—0.936  | ...  | 1.481<br>—1.482         | ...                        | —4   | ...                                    | ...             | ...              | ...   |
| 47 Montan wax<br><i>Lignite wax</i>                 | ...  | ...  | ...                     | ...                        | ...  | ...                                    | 80—86           | ...              | Unsap. 9.98%  |
| 48 Mustard seed oil<br><i>Sinapis nigra</i> (black) | 0.9155   | ..   | 1.4672                  | 1.4665<br>(20°)            | —15 to<br>—16  | 6—8                                    | ...             | 9—17             | Black 95.05<br>—95.32   |
| <i>Sinapis alba</i> (white)                         | 0.9142   | ...  | 1.4750<br>(15.5°)       | 1.4630<br>(20°)            | —15 to<br>—16.3  | 9—10                                   | ...             | 12—16            | White 95.21<br>—96.7  |
| 49 Neat's foot oil                                  | 0.9164   | 0.879 ( $\frac{100}{100}$ )                                  | 1.4681 (20°)            | ...                        | ...  | 26.1—26.5                              | ...             | 28.5<br>—29.8    | 95.2—95.5   |
| 50 Nut oil, see Walnut oil.                         |  |  |                         |                            |  |  |                 |                  | 742   |
| 51 Olive kernel oil                                 | 0.9184—<br>0.9193  | ...  | 1.4673—<br>1.4688 (25°) | ...                        | ...  | ...                                    | ...             | ...              | ...   |
| 52 Olive oil<br><i>Olea europea sativa</i>          | 0.9155—<br>0.9180 &<br>0.9203                                | 0.8430 ( $\frac{99}{15.5}$ )<br>0.8749 ( $\frac{100}{100}$ ) | 1.4698                  | 1.4410                     | 3 to 10  | 16.9—26.4                              | ...             | 19—29.3          | 94—96   |
| 53 Palm kernel oil<br>or Palm nut oil               | 0.9119 ( $\frac{40}{15.5}$ )<br>0.8731 ( $\frac{99}{15.5}$ ) | ...  | 1.4431 (60°)            | 1.4310                     | 23—24  | 20—25.5                                | 28—30           | 20.7—<br>28.5    | 91.1  |
| 54 Palm oil<br><i>Elaeis guineensis</i>             | 0.9209<br>—0.9245<br>(15)                                    | 0.8369 ( $\frac{99}{15.5}$ )<br>0.8701 ( $\frac{100}{10}$ )  | 1.4510 (60°)            | ...                        | 31—39  | 35.8—45.5                              | 35—42           | 47.7—50          | 94.2—97   |
| 55 Peach kernel oil<br><i>Prunus persica</i>        | 0.9198   | ...  | ...                     | ...                        | Below<br>—20   | 13—13.5                                | ...             | 10—18.9<br>& 3.5 | 94.0  |

| Unsaponifiable matter. | Saponification value<br>ingrms. KOH for<br>oil, &c. | Neutralisation value<br>of fatty<br>acids. | Iodine value %    |                 | Mau-<br>mené's<br>Test,<br>0°C. | Reichert-<br>Meissl<br>value<br>cc. $\frac{N}{10}$ KOH. | Mean<br>mol.-wt.<br>of fatty<br>acids. | Acid value. | Other data.  |
|------------------------|---|--|-------------------|-----------------|---------------------------------|---|--|-------------|--|
|                        |   |  | Oils, &c.         | Fatty<br>acids. |                                 |   |  |             |  |
| 46                     | 0.6—1.6   | 188.7—193                                  | ...               | 140—180         | ...                             | 123—128   | 1.1—1.2                                | 3.53—11.74  |  |
| 47                     | ...   | 126.58                                     | 123.01            | ...             | ...                             | ...   | ...                                    | ...         |  |
| 48                     | ...   | 173.2<br>—175.8                            | 176.7 to<br>187.1 | 98.8—113        | 42—43                           | 299.8—<br>317.8   | ...                                    | 1.36—7.35   | Not quite soluble in hot<br>ether, soluble in $\text{CCl}_4$ .<br>Viscosity 355—425. |
| 49                     | ...   | 170.3<br>—177.8                            | 181—185.8         | 92.1—103        | 44.45<br>—49.5                  | 301.9—<br>310.3   | ...                                    | ...         | Viscosity 402.   |
| 50                     | ...   | 194.3<br>—199                              | 200.6<br>—206.3   | 66—76           | 42.2—49<br>& 56—58              | ...   | 1.0                                    | ...         | Acetyl value 22.0.   |
| 51                     | ...   | 181.2<br>—183.8                            | ...               | 86.99<br>—87.8  | ...                             | ...   | ...                                    | ...         |  |
| 52                     | 0.46—1.0  | 188.7—196                                  | 193               | 79—88           | 35—47                           | 279.4<br>—286   | 0.6                                    | 0.4—24      | Sp. temper. reaction 89-95   |
| 53                     | ...   | 242.4—250                                  | 251.7—265         | 10.3—17.5       | ...                             | 211—<br>222.8   | 5—7.6                                  | 8.36        |  |
| 54                     | 0.35—0.7  | 196.3<br>—205.52                           | 204—207           | 53—57.4         | ...                             | 270—273   | 0.74—1.87                              | ...         |  |
| 55                     | ...   | 189.1<br>—192.5                            | 205.0<br>—209.9   | 92.5—110.1      | 42—43                           | 278.8   | ...                                    | 2.5—6.4     | Pink elaidin.  |



# OILS, FATS, AND WAXES—continued.

| Name and Source.   | Sp. Gr. at 15.5°        |  | Refractive index.     |                         | Solidifying Pt. °C. for oils, &c. fatty acids | Titer test on fatty acids | Melting Pt. °C. |              | % Insoluble fatty acids and unsaponifiable matter. |
|--|-------------------------|--|-----------------------|-------------------------|---|---------------------------|-----------------|--------------|--|
|  | Oils, &c.               | Fatty acids.   | Oils at 15°C., &c.    | Fatty acids at 60°C.    |   |                           | Oils, &c.       | Fatty acids. |  |
| 56 Peanut oil, see Arachis oil.                              |                         |  |                       |                         |   |                           |                 |              |  |
| 57 Poppy seed oil<br><i>Papaver somniferum</i>               | 0.924—0.927 (15°)       | 0.886 ( $\frac{100}{100}$ )                                  | 1.4773                | 1.4506                  | -18   | 15.4—16.2                 | ...             | 20—21        | 94.97—95.38  |
| 58 Porpoise oil<br><i>Delphinus phocaena</i>                 | 0.9258 (15°)            | ...  | ...                   | ...                     | -16   | ...                       | ...             | ...          | 91.04  |
| 59 Pumpkin seed oil<br><i>Cucurbita pepo</i>                 | 0.9197                  | ...  | ...                   | ...                     | -16   | ...                       | ...             | 26.5—29.8    | 96.2   |
| 60 Radish seed oil<br><i>Raphanus sativus</i>                | 0.9163                  | ...  | 1.471—<br>1.472 (20°) | 1.4625—<br>1.4630 (20°) | -10 to<br>-17.5                               | S.P. 7—15                 | ...             | 11—20        | 95.01—95.94  |
| 61 Rape oil<br><i>Brassica campestris</i>                    | 0.9132<br>—0.9159       | 0.8758 ( $\frac{100}{100}$ )<br>0.8438 ( $\frac{99}{15.5}$ ) | 1.4720<br>—1.4757     | 1.4491                  | -10 to<br>+10                                 | 11.7—13.6                 | ...             | 18.3—21.5    | 91.56—96.3   |
| 62 Sardine oil<br><i>Clupea sardinus</i>                     | 0.9330 (15°)            | ...  | ...                   | ...                     | ...   | ...                       | ...             | ...          | 95.6—97.08   |
| 63 Seal oil<br><i>Phoca vitulina</i> and other varieties     | 0.9249—<br>0.9263 (15°) | 0.9156—<br>0.9172 (15°)                                      | 1.4776                | ...                     | -2 to -3                                      | 13—17                     | ...             | 14—33        | 92.8—95.85   |
| 64 Sesame oil<br><i>Sesamum orientale</i> and <i>indicum</i> | 0.9203                  | ...  | 1.4748<br>—1.4762     | 1.4461                  | -4 to -6                                      | 21.2—23.8                 | ...             | 23—32        | 95.8   |
| 65 Shea butter<br><i>Bassia Parkii</i>                       | 0.859—0.918             | ...  | ...                   | ...                     | 17—18   | 48.6—53.8                 | 23.3—25.3       | 39.5—56      | 91.7—96.5  |
| 66 Soya bean oil<br><i>Dolichos soja</i>                     | 0.9222—<br>0.9279 (15°) | ...  | 1.4680 (40°)          | 1.465 (27.5°)           | -8 to<br>-15                                  | 21.2                      | ...             | 26—29        | 95.5   |
| 67 Spermaceti<br><i>Physeter macrocephalus</i>               | 0.905—<br>0.960 (15°)   | ...  | 1.433 (80°)           | ...                     | 41—49   | ...                       | 42—44.5         | ...          | ...  |

| Unsaponifiable matter. | Saponification value<br>mgms. KOH for oil, &c. | Neutralisation value<br>of fatty acids. | Iodine value %  |                 | Mau-<br>mené's<br>Test,<br>0°C. | Reichert-<br>Meissl<br>value<br>cc. $\frac{N}{10}$ KOH. | Mean<br>mol.-wt.<br>of fatty<br>acids. | Acid value. | Other data.                             |
|------------------------|--|---|-----------------|-----------------|---------------------------------|---|--|-------------|---|
|                        |  |   | Oils, &c.       | Fatty<br>acids. |                                 |   |  |             |   |
| 56 0.43                | 189—196.8                                      | 199                                     | 132.6           | 139             | 86—88.5                         | 0.00  | ...                                    | 0.7—11      |   |
| 57 3.7                 | 195  | 203                                     | —157.5<br>88.3  | ...             | ...                             | 47  | ...                                    | 5.0         |   |
| 58 3.7                 | 195  | 203                                     | —119.4<br>119.7 | ...             | ...                             | ...   | 284.7                                  | ...         |   |
| 59 ...                 | 188.4<br>—190.2                                | 197                                     | —130.7          | ...             | ...                             | ...   | ...                                    | ...         |   |
| 60 ...                 | 173.8<br>—181.6                                | 182.6<br>—189.5                         | 92.8<br>—112.4  | 97.1<br>—115.3  | 51                              | ...   | ...                                    | ...         | Viscosity (seconds at<br>70° F.) 385.3. |
| 61 0.58—1.0            | 170.6<br>—178.7                                | 185                                     | 93.5<br>—103.6  | 99.8<br>—105.6  | 49—60                           | ...   | 307<br>—321.2                          | 1.4—13.2    | Sp. temper. reaction<br>125—144.        |
| 62 0.48—1.01           | ...  | ...                                     | 161—192         | ...             | ...                             | ...   | 285.7<br>—299.5                        | 4.6—24.7    |   |
| 63 0.38—1.1            | 178—196  | 190.4—198                               | 127—193         | 186.5<br>—201.8 | ...                             | 0.96—1.69   | ...                                    | 1.9—40      | Acetyl value 16.5.                      |
| 64 0.95—1.32           | 188.5<br>—190.4                                | 196—201.6                               | 103—114.5       | 108.9—112       | 63—72                           | ...   | 286                                    | 0.2—10      |   |
| 65 3.5                 | 171.8<br>—192.3                                | ...                                     | 56.2—67.2       | 55.6—57.2       | ...                             | ...   | ...                                    | 29.4        |   |
| 66 0.22                | 190.6<br>—192.5                                | ...                                     | 124—143         | 122             | 87—88                           | ...   | ...                                    | 1.75—7      |   |
| 67 ...                 | 120.6<br>—134.6                                | ...                                     | 3.8             | ...             | ...                             | ...   | ...                                    | 0—1         | Acetyl value 2.63.                      |

## OILS, FATS, AND WAXES—continued.

| Name and Source.                                     | Sp. Gr. at 15.5°        |                              | Refractive index.      |                      | Solidifying Pt. °C. for oils, &c. | Titer test on fatty acids °C. | Melting Pt. °C. |              | % Insoluble fatty acids and unsaponifiable matter. |
|--|-------------------------|------------------------------|------------------------|----------------------|-----------------------------------|-------------------------------|-----------------|--------------|--|
|  | Oils, &c.               | Fatty acids.                 | Oils at 15°C., &c.     | Fatty acids at 60°C. |                                   |                               | Oils, &c.       | Fatty acids. |  |
| 68 Sperm oil<br><i>Physter macrocephalus</i>         | 0.875—0.884             | 0.899                        | 1.4646—<br>1.4655(20°) | ...                  | ...                               | 11.1—11.9                     | 5.5             | 13.3—24      | 60—67  |
| 69 Stag fat<br><i>Cervus elaphus</i>                 | 0.9670 (15°)            | 0.9685 (15°)                 | ...                    | ...                  | 39—48                             | S.P. 46—48                    | 49—52           | 49.5—52      | ...  |
| 70 Stickle-back oil<br><i>Gasterosteus tracherus</i> | ...                     | ...                          | ...                    | ...                  | ...                               | ...                           | ...             | ...          | 95.78  |
| 71 Sunflower oil<br><i>Helianthus annuus</i>         | 0.924—<br>0.926 (15°)   | ...                          | 1.4611<br>(60°)        | 1.4531               | —16 to<br>—18.5                   | S.P. 17<br>—18                | ...             | 17—24        | 95   |
| 72 Tallow (Mutton)                                   | 0.937—0.953             | ...                          | 1.4501<br>(60°)        | 1.4374               | 36—41                             | 43.2—46.1                     | 44—49           | 46—54        | 95.54  |
| Tallow (Beef), see Beef<br>Tallow                    |                         |                              |                        |                      |                                   |                               |                 |              |  |
| 73 Tung oil, see Chinese<br>or Japanese Tung oil.    |                         |                              |                        |                      |                                   |                               |                 |              |  |
| 74 Walnut oil<br><i>Juglans regia</i>                | 0.9259                  | ...                          | 1.4804                 | ...                  | —27.5                             | S.P. 16                       | ...             | 15—20        | 95.4   |
| 75 Whale oil<br><i>Balena</i> species                | 0.9170 (15°)<br>—0.9272 | 0.8922 ( $\frac{100}{100}$ ) | 1.4762<br>(20°)        | 1.4348               | below —22.9—23.9                  | ...                           | ...             | 27           | 93.5   |
| 76 White mustard oil, see<br>Mustard oil.            |                         |                              |                        |                      |                                   |                               |                 |              |  |
| 77 Wool fat, Wool wax or<br>Wool grease              | 0.941—<br>0.945 (17°)   | ...                          | 1.4781—<br>1.4822(40°) | ...                  | 30—30.2                           | S.P. 40                       | 31—42.5         | 41.8         |  |

| Unsaponifiable matter. | Saponification value mgrams. KOH for oil, &c. | Neutralisation value of fatty acids. | Iodine value %  |                 | Mau-<br>mené's<br>Test,<br>0°C. | Reichert-<br>Meissl<br>value<br>cc. $\frac{N}{10}$ KOH. | Mean<br>mol.-wt.<br>of fatty<br>acids. | Acid value. | Other data.                                  |
|------------------------|---|--------------------------------------|-----------------|-----------------|---------------------------------|---|--|-------------|--|
|                        |   |                                      | Oils, &c.       | Fatty<br>acids. |                                 |   |  |             |  |
| 68 37—41.5             | 123.4<br>—147.4                               | ...                                  | 70.4—96.4       | 83.2<br>—98.74  | 51                              | 0.60  | 281—300                                | 2—4         | Butyrefractometer at 40°C<br>44.5 "degrees." |
| 69 ...                 | 199.9<br>—203.5                               | 201.3                                | 19.3—25.7       | 23.6            | ...                             | ...   | ...                                    | ...         |  |
| 70 1.73                | 183.2<br>—192.6                               | ...                                  | 162             | ...             | ...                             | ...   | 287.4                                  | 21.6        |  |
| 71 0.31                | 188—194                                       | 201.6                                | 119.7—135       | 124—134         | 72—75                           | ...   | ...                                    | 11.2        |  |
| 72 ...                 | 192—195.2                                     | 198                                  | 34.8—46.2       | 34.8            | ...                             | ...   | 275—285                                | 1—50        | Ether-insoluble bromides,<br>27.8%           |
| 73                     |   |                                      |                 |                 |                                 |   |  |             |  |
| 74 ...                 | 188.7<br>—197.3                               | ...                                  | 132.1<br>—151.7 | 150.05          | 96—110                          | ...   | ...                                    | ...         |  |
| 75 0.2—4.0             | 187.9<br>—194.2                               | ...                                  | 110—146         | 130.3—132       | 85—92                           | Reichert<br>value<br>0.7—2.04                           | ...                                    | 0.5—60      |  |
| 76                     |   |                                      |                 |                 |                                 |   |  |             | ...  |
| 77 ...                 | 102.4   | ...                                  | 17.1—28.9       | 17              |                                 | ...   | 327.5                                  | ...         |  |

## ESSENTIAL OILS.

T. H. DURRANS, M.Sc. (Lond.), F.I.C.

When examining essential oils, it should be remembered that, as they are natural vegetable products, their composition and character are greatly affected by climatic and other conditions under which they have been formed. It is therefore inadvisable to stipulate inelastic specifications; careful judgment must be exercised, as the sophisticator is not slow to take advantage of this situation. Among other precautions, tests should invariably be made of the odour; such tests will not infrequently indicate in which direction adulteration should be sought. In cases of doubt it is often useful to compare the oil under examination with one of undoubted purity.

The tests usually applied are physical and chemical. The physical tests comprise: specific gravity; optical rotation; refractive index; solubility in alcohol; melting or solidifying point; distillation tests. The chemical tests include estimations of certain general and specific constituents of the oils, such as: acids, esters, alcohols, phenols, aldehydes and ketones.

### Physical Tests.

(1) *Specific gravity.* Specific gravity bottles of 50 cc. capacity are the most suitable instruments for this determination; pyknometers are specially useful if the quantity of oil available is small. The coefficient of expansion of essential oils is high, being of the order of 0.001; it is therefore necessary to adjust carefully the temperature at which the determination is made. The temperature most generally employed is 15°C.; sometimes 60°F., i.e., 15.5°C., is used. The United States Pharmacopœia has adopted a standard temperature of 25°C., and this is generally used in warm climates. Higher temperatures are also necessary for oils which are solid at 15°C., such as otto of rose (30°C.) and aniseed oil (20°C.). The specific gravity bottle or pyknometer must be calibrated at the temperature used in making the test.

(2) *Optical rotation.* This is expressed in terms of the angular rotation of sodium light passing through a 100 mm. length of the oil at 20°C. Accurate temperature adjustment, although desirable, is not essential, the error produced by a temperature variation of 1°C. or 2°C. being relatively small.

It is always advisable thoroughly, but quickly, to filter the oils as a slight cloudiness makes accurate adjustment difficult; oils having a green colour, such as bergamot, are particularly opaque to sodium light, and it is generally necessary to

employ short containing tubes. With some oils of very low optical activity, such as fennel oil, the greatest care must be taken, and the zero of the instrument must be carefully checked.

(3) *Refractive index.* The most suitable instrument is the jacketed Hilger-Abbé refractometer, which has the great advantages that a determination accurate to 1 or 2 in the fourth decimal place may be made with only two or three drops of the oil, and that ordinary daylight may be used. Other instruments occasionally employed are the Pulfrich and the Féry.

The temperature of the oil is adjusted carefully to the standard temperature of 20°C.; the U.S.P. quotes 25°C., and there is a general tendency for the use of this higher temperature. The refractive index diminishes with rise of temperature; an approximate correction which may be applied is  $\pm 0.00045$  per 1°C.

(4) *Solubility in alcohol.* This test is conducted by shaking 1 cc. of the oil in a stoppered graduated 10 cc. measuring cylinder with alcohol of definite strength, added 1 cc. at a time, until complete solution is obtained. The usual strengths of alcohol employed are 90%, 80% and 70% by volume, but both higher and lower strengths are occasionally used. The test should be conducted at a temperature of 20°C., but this precaution is not invariably observed.

This test is of great value in testing terpeneless and sesquiterpeneless oils. The former are generally soluble in less than 5 volumes of 80% alcohol, and the latter in less than 5 volumes of 70% alcohol. Certain essential oils, especially stale or resinified oils, never yield a completely clear solution, while other oils first dissolve, and on the addition of more alcohol become cloudy. The solubility test was formerly practically the sole criterion by which Ceylon citronella oil was judged (Schimmel's test), but of recent years more scientific tests have been used.

Proposals have been made to establish a test known as the "solubility value." This value is determined by dissolving 5 cc. of the oil in 10 cc. of absolute alcohol (67 O.P.), and then adding water from a burette until a permanent turbidity is just produced. The number of cc. of water added multiplied by 100 is termed the "solubility value."

For specific gravities of alcohol-water mixtures, see "Physico-Chemical Constants" section.

(5) *Melting- and solidifying-points.* This test is only applicable to those oils which are solid at normal temperatures, such as aniseed, fennel, and rose oils. It can be



carried out in an ordinary test-tube, except when highly accurate results are required, in which case it is best to employ a Beckmann freezing-point apparatus. The thermometer employed for the determination should be accurate and graduated to one-tenth degrees over a range of  $-10^{\circ}$  to  $+50^{\circ}\text{C}$ .

Difference of opinion exists regarding the relative accuracies of the melting-point and the solidifying-point determinations. In the opinion of the writer, the solidifying-point, if the operation be properly carried out, is more definite than the melting-point, but in any case, the "personal equation" of the operator tends to vary the results.

It is advisable to make an approximate estimation of the solidifying- and melting-points before making an accurate determination. Accurate results may be obtained as follows:

A convenient quantity of the oil, say 5 cc. of aniseed oil, is placed in a clean, dry, stout-walled test-tube, the oil completely melted, the tube immersed in iced water (a freezing mixture of ice and salt may be used if necessary, but excessive supercooling must be avoided), and the oil gently stirred with the thermometer. When the temperature has dropped about  $5^{\circ}$  below the solidifying-point of the oil, previously determined, the test-tube is removed, the outside quickly dried, and crystallisation induced by the addition of a small crystal of a separately solidified portion of the oil. The oil is stirred vigorously, and the maximum temperature attained is noted; this temperature is the solidifying-point. The stirring is continued until the oil melts, using if necessary an air-bath 4 or 5 degrees above the solidifying temperature of the oil, and the temperature noted at which liquefaction takes place, usually a degree or two above the solidifying-point. Essential oils, being mixtures, do not have very definite melting-points, and it is difficult to decide which is the exact temperature of liquefaction; it is sometimes considered preferable to determine the temperature at which the liquid becomes clear or completely molten.

(6) *Distillation tests.* These as a rule are not resorted to unless adulteration is suspected. Sometimes, however, failing a better method, a particular constituent of an oil is roughly estimated by fractional distillation, *e.g.*, anethole in aniseed oil. If adulteration is suspected, the best procedure is to distil the oil into 10% fractions, and to examine the functions, comparing them with fractions obtained under identical conditions from a similar oil of undoubted purity. It is generally necessary to distil under diminished pressure (10 to 20 mm.) in order to avoid decomposition. The determination of the refractive indices of the various fractions



is usually sufficient to indicate adulteration. The boiling ranges and odours also serve as very useful guides. The procedure which should follow will depend on the results obtained and must be left to the judgment of the operator. Often it is possible to isolate by fractional distillation the substance used for the adulteration. The test is sometimes conducted by taking fractions over definite boiling-point ranges instead of in 10% fractions.

(7) *Odour test.* The quality of an oil can often be gauged fairly accurately by smelling a drop rubbed on the back of the hand, but it is better to make a comparison with an oil of known authenticity and quality, by placing a drop of each oil respectively on two pieces of filter-paper, and smelling them alternatively; it must be remembered that a process of fractional evaporation is proceeding continually. Advantage may be taken of this fractional evaporation by comparing slips of filter-paper impregnated with the oil at different times, after partially allowing to evaporate. The odour test may also be conducted by comparing the odours in two similar beakers, each covered with a clock-glass, and at the bottom of which have been placed just one drop of the two oils respectively. The tests should be conducted in an odour-free atmosphere, and under clean conditions.

### Chemical Tests.

(1) *Acid value and Ester value.* The acid value estimation is not usually of much critical value, but is a necessary preliminary to a subsequent ester determination, and may be conducted with the sample used for the latter. Most oils are practically neutral, but tend to acquire acidity by oxidation.

For the dual determination the procedure is as follows:—Into an alkali-free glass flask of about 200 cc. capacity is weighed out accurately 2 to 5 grm. of the oil (according to the probable magnitude of the ester content), about 2 cc. of neutral distilled water is added, and the free acidity titrated with N/10 sodium or potassium hydroxide, using phenolphthalein as indicator. The acid value is expressed as the number of milligrams of potassium hydroxide required to neutralise one gram of the oil.

25 cc. of N or N/2 alcoholic sodium or potassium hydroxide solution (recently checked) is added, and the solution refluxed on a water-bath for one to two hours; the solution is cooled and the excess of alkali titrated with N or N/2 sulphuric or hydrochloric acid.

If the identity of the ester in the oil be unknown, the results may be returned in terms of milligrams of potassium

hydroxide consumed by one gram of the oil (ester number, but it is usual to refer the result to the predominating ester, e.g., linalyl acetate in lavender or bergamot oils; geranyl tiglate in geranium oil; menthylacetate in peppermint; methyl salicylate in wintergreen oil. The ester percentage is calculated from the following formula:—

$$\frac{\text{No. of cc. of N. alkali} \times \text{Mol. wt. of ester}}{10 \times \text{Wt. of oil}}$$

The following are the molecular weights of a few of the more usually occurring esters:—

|  |     |  |     |
|--|-----|--|-----|
| Benzyl acetate .. .. .                             | 150 | Menthyl and citronellyl acetates .. .. . | 198 |
| Methyl anthranilate .. .. .                        | 151 | Geranyl tiglate .. .. .                  | 236 |
| Methyl salicylate .. .. .                          | 152 | Santalyl acetate .. .. .                 | 262 |
| Sabinyal acetate .. .. .                           | 194 |  |     |
| Geranyl, linalyl, terpinyl, and bornyl acetates .. | 196 |  |     |

It should be remembered that other bodies, such as aldehydes and lactones, may be included in the ester value as determined by hydrolysis with caustic alkali. For the detection of the addition of substances which elevate the ester value fictitiously, see "Detection of adulterants."

(2) *Estimation of alcohols.* Alcohols, such as geraniol, menthol, linalool, etc., are estimated by first converting them into their acetic esters, and then re-determining the ester value of the acetylated oil.

The process has been standardised to some extent, but variations are necessary as indicated in the case of certain oils:—

10 cc. of the oil is boiled gently under a reflux air-condenser for 2 hrs. with 20 cc. of acetic anhydride (95—100%) and 2 gm. of recently-fused, anhydrous sodium acetate. The liquid is cooled, about 100 cc. of water added, and warmed on the water-bath to about 80°C for 15 mins. with occasional shaking, in order to decompose the excess of acetic anhydride. The mixture is transferred to a separating-funnel, and the oil washed three times with cold water (or brine, if the separation is poor due to the formation of an emulsion), then with 1% sodium carbonate solution until the mixture remains distinctly alkaline, and finally with distilled water until neutral. The oil is separated, and dried over neutral anhydrous sodium sulphate, filtered, and the new ester value estimated as previously detailed.

The percentage of alcohols may be calculated from the formula:—

$$\frac{\text{No. of cc. of N. alkali} \times \text{Mol. wt. of alcohol}}{10 \times (\text{Wt. of acetylated oil} - 0.042 \times \text{No. of cc. N. alkali})}$$

$$10 \times (\text{Wt. of acetylated oil} - 0.042 \times \text{No. of cc. N. alkali})$$

If the original oil contained esters other than acetates, this formula does not give strictly accurate results; for more accurate results it is necessary to hydrolyse the oil before acetylating, and then to calculate the results to the original oil. The amount of free alcohol may be calculated as follows:

$$\% \text{ free alcohol} = \frac{(B - A) Y}{0.42106 (1335.5 - B)}$$

where:

A is the saponification value of the original oil;

B " " " " " after acetylating;

Y " " molecular weight of the alcohol, if monohydric

The following are the molecular weights of the most usually occurring alcohols:—

|  |     |
|--|-----|
| Benzyl alcohol                         | 108 |
| Phenyl ethyl alcohol                   | 122 |
| Geraniol, linalool, terpineol, borneol | 154 |
| Rhodinol, citronellol, menthol         | 156 |
| Santalol                               | 220 |

The alcohols linalool and terpineol are dehydrated by the action of acetic anhydride, terpenes being formed, but fairly accurate results may be obtained if the oil be first diluted with an equal weight of turpentine or xylene, a blank having been performed on the diluent and allowed for.

Certain oils, such as citronella, contain the aldehyde citronellal, which, under the action of acetic anhydride, isomerises to the ring alcohol isopulegone, the alcohol value being raised correspondingly. In such cases it is usual to return the result as obtained by the standard method as "total acetylisable constituents," calculated as geraniol. Java citronella oil, usually having a total acetylisable constituent value of over 90%, needs more acetic anhydride than allowed in the standard method, to acetylate it completely; 30 cc. of 95–100% acetic anhydride should be used in place of the usual 20 cc.

It is becoming more usual to differentiate between the geraniol and the citronellal of Java citronella oils, and this is done by converting the aldehyde into its oxime, thus preventing its isomerisation into isopulegol, and then re-estimating the alcohols. The procedure is as follows:—

10 gm. of hydroxylamine hydrochloride is dissolved in 25 cc. of water, and a solution of 10 gm. of potassium carbonate in 25 cc. of water added; the mixture is filtered and shaken thoroughly with about 10 gm. of the oil for 2 hrs. at 15°–18°C. The oil is separated, dried over neutral

anhydrous sodium sulphate, filtered, and treated as described for alcohol estimations.

The difference between the value thus found for the geraniol itself and the value for the total acetylisable constituents calculated as geraniol, represents the citronellal content.

The alcohol citronellol may be approximately estimated in the presence of geraniol, *e.g.*, in otto of rose, by treatment with 100% formic acid. The geraniol is dehydrated to a terpene, but the citronellol is formylated. The process is as follows:—

A mixture of 10 cc. of the oil with 10 cc. of 100% formic acid (Sp. Gr. 1.22) is gently refluxed for 1 hr., then cooled, shaken with 100 cc. of water, the oil separated, and submitted to the process for the determination of esters. The percentage of citronellol is given by the formula:—

$$\text{No. of cc. of N. alkali} \times 15.6$$

---


$$\text{Wt. of formylated oil} - (\text{No. of cc. of N. alkali} \times 0.028)$$

(3) *Aldehydes and ketones.* Two methods are in general use; one is applied to oils containing a large proportion of aldehyde or ketone, and the other, when these are present only in small proportions, *e.g.*, up to 10%.

*Sulphite method.* This is suitable for the estimation of aldehyde in oil of lemongrass, cassia, cinnamon bark, almond, terpeneless and sesquiterpeneless lemon, and methyl ketones such as methyl heptenone.

5 or 10 cc. of the oil is accurately pipetted into a flask of 150 cc., or, better, 250 cc. capacity, the neck of which is long and narrow and 10 cc. of which is graduated in 0.1 cc. (Cassia flask). To this is added about an equal volume of hot sodium bisulphite solution (30—35% strength), and the mixture well shaken for a few mins.; frequently, however, the mixture becomes solid almost immediately, and further quantities of bisulphite solution are added from time to time with frequent shaking, and the whole is kept hot on a boiling-water bath until the solid first formed is completely dissolved, and only oil remains; the flask is then filled with bisulphite solution, so as to bring the unabsorbed oil up into the graduated portion of the neck; it is then set aside to cool, and for the unabsorbed oil to float out. The difference between the original volume of the oil and that unabsorbed is a measure by volume of the aldehyde content of the oil.

Cassia oil is not infrequently “adjusted” by the addition of colophony; in such cases, it is advisable to prolong the heating for several hours, as this aids the ultimate floating out of the unabsorbed portion. In cases where an emulsion

forms between the oil and the aqueous solution so as to obscure the partition, it can sometimes be broken up by the addition of a known volume of benzene or petroleum ether, the addition being allowed for in the final reading.

The process is sometimes carried out by using neutral sodium sulphite solution, instead of bisulphite; in this case, sodium hydroxide is formed during the reaction, and must be neutralised by the gradual addition of dilute acid until no further alkalinity is shown by phenolphthalein. This method is preferable to the other in that it shows when the absorption is complete. It generally gives slightly lower results than the bisulphite method, as under these conditions, bodies such as methyl heptenone are only very slowly absorbed; hence for lemon-grass oil the neutral sulphite method is to be preferred. The amount of acid added to neutralise the alkalinity developed is also a measure of the aldehydic content of the oil but, owing to the indefinite "end point," the method is not employed.

*Hydroxylamine method.* This method is the best for the estimation of citral in oils of lemon, citron, limes (H.P.), etc. It is also reliable for other aldehydes, and is used when the sulphite method is not suitable on account of a low aldehydic content. This method requires considerable practice, even in the hands of experienced chemists. It is conducted as follows:

20 grm. of oil of lemon (for example) is weighed accurately into a 250 cc. conical flask, and to it are added in the order named, 20 cc. of alcohol (60 O.P.), 20 cc. of N/2 hydroxylamine hydrochloride in 80% alcohol, and 8 cc. of N. alcoholic potassium hydroxide. The mixture is gently boiled on a water-bath for exactly one hour, under a really efficient reflux condenser. The flask is then cooled, and the contents diluted to about 250 cc. by washing through the condenser with freshly-boiled distilled water. The undecomposed hydroxylamine hydrochloride is then exactly neutralised with N/2 potassium hydroxide, using phenolphthalein as indicator, and the hydroxylamine thus liberated titrated with N/2 sulphuric acid, methyl orange being used as an external indicator on a spotting tile. The end point is not very distinct, and the titration must be done rapidly. A blank test is conducted under exactly the same conditions, the oil being omitted. The difference between the titrations with methyl orange represents, in terms of N/2 cc., the hydroxylamine combined with the aldehyde. In the case of lemon oil, this figure must be multiplied by 0.38 to give the percentage by weight of citral in the oil (*cf.* British Pharmacopœia). For other mono-aldehydes, the percentage is given by—

(No. of cc. of N/2 hydroxylamine  $\times$  Mol. wt. of aldehyde) / 400.



The hydroxylamine hydrochloride solution used for this process should not be made up in bulk, as it tends to give erratic results after the lapse of a day or two. The method gives results 5 to 10% low, and is not suitable for use with oils containing large proportions of aldehyde, nor for the estimation of citronellal.

(4) *Phenols*. These are estimated by absorption in a "Cassia flask" (see aldehyde estimation—sulphite method) by 3% sodium hydroxide or 5% potassium hydroxide. 5 or 10 cc. of the oil, accurately pipetted, are shaken in the flask with 100 to 150 cc. of the alkali solution, the mixture being heated on a boiling water-bath. The absorption is complete after about 1 hr., and the flask is then filled up with the alkali solution, set aside for about 12 hrs. to allow the oil to separate out, and measured. The process is suitable for estimating eugenol, thymol, etc.; the results tend to be too high on account of the absorption of small quantities of non-phenols, and for this reason the use of stronger alkali solution is to be avoided.

(5) *Estimation of eucalyptole (cineole)*.

*Phosphoric acid method*. This is the official method of the British Pharmacopœia, but is not very accurate. Concordant results can only be obtained by experienced operators. It is the method usually adopted in commerce, but a more accurate method, the cresinol method, is replacing it.

The phosphoric acid method is conducted as follows:—10 to 20 grm. of oil is weighed accurately into a small beaker, and to it are added, drop by drop, with stirring and cooling one to one-and-a-half times its weight of pure phosphoric acid of Sp. Gr. 1.750. The crystals which rapidly form are quickly but thoroughly pressed between dry filter-paper, all adherent liquid being removed as far as possible; they are then placed in an accurately graduated measuring cylinder, and mixed with warm water. The eucalyptole-phosphoric acid compound is thereby decomposed, and the eucalyptole separates out and can be measured after cooling; the weight is calculated by multiplying the volume by 0.93. In order to check the accuracy of the estimation the oil layer should be separated, dried over anhydrous sodium sulphate, filtered, and its melting-point ascertained; this should not be lower than  $-3^{\circ}\text{C}$ . (pure eucalyptole melts at  $+1.2^{\circ}\text{C}$ .). It is well to remember that eucalyptole is a body of relatively high volatility, B.Pt.  $177^{\circ}\text{C}$ . In order to aid the removal of the terpenes, the crystals may be washed on a Buchner funnel with dry petroleum ether of low boiling point, but all moisture, even atmospheric, must be carefully excluded, as water readily

decomposes the compound, and low results may be obtained. The phosphoric acid method is not suitable for oils containing less than 40% of eucalyptole; such oils may have the eucalyptole content raised by the addition of a known proportion of pure eucalyptole, or by careful fractional distillation before performing the estimation.

*Cresineol method.* This method consists in determining the freezing-point of a mixture of *o*-cresol with the eucalyptus oil; it gives slightly higher results than the phosphoric acid method, but the probability of error is within the limits of  $\pm 3\%$ . It is carried out as follows:—

Into a stout-walled test-tube, about 15 mm. by 80 mm. in size, are weighed out accurately exactly 3 grm. of the oil, and 2.1 grm. of melted *o*-cresol. The tube is then inserted, through a suitably bored cork, into a wide-mouthed bottle. The mixture is stirred with a thermometer, graduated  $0-100^{\circ}\text{C}$ . in  $1/10\text{th}$  degrees, and the solidifying-point noted. The mixture is then completely melted, and the solidifying-point again noted, the operations being repeated until concordant results are obtained. With oils which are low in eucalyptole content it is sometimes necessary to “seed” the superfused liquid with a crystal of the eucalyptole-cresol compound “cresineol.” Pure cresineol solidifies at  $55.2^{\circ}\text{C}$ . and pure *o*-cresol at  $30^{\circ}\text{C}$ . The percentage of eucalyptole is estimated from the following table, or, better, from a curve constructed from the table:—

| % Eucalyptole. | F. Pt.  | % Eucalyptole. | F. Pt.  |
|----------------|---------|----------------|---------|
| 100            | 55.2°C. | 70             | 42.2°C. |
| 95             | 53.5    | 65             | 39.3    |
| 90             | 51.5    | 60             | 35.8    |
| 85             | 49.1    | 55             | 31.3    |
| 80             | 46.8    | 50             | 27.6    |
| 75             | 44.5    | 45             | 24.2    |

The freezing point is the temperature at which the solid resineol separates from the mother liquor. The mixture is permanently fluid at the temperature of the test.

The method may also be applied to oils of low eucalyptole content, such as spike, lavender, and rosemary, by the addition of a known proportion of pure eucalyptole before performing the determination.

### 6) *Stearoptene or fixed-residue.*

This estimation is usually only carried out with oils obtained by expression; it is also of value if adulteration with substances of high boiling-point is suspected. It is carried out by evaporating a known weight (10 grm.) of the oil on a boiling water-bath, until the loss in weight in 10 to 15 mins. is negligible. The character of the residue



should be noted, and, if thought necessary, further tests applied. The following are some typical results for pure oils: lemon, 2—6%; sweet orange, 1·5—4%; bitter orange, 2·5—4·5%; tangerine, 2—4%; bergamot, 4·5—6·5%; H.P. limes, 9—18%; rose (Bulgarian), 15—20%.

### *Detection of adulterants.*

Adulteration is often detected by abnormality of the physical or chemical data usually determined. It is impossible to do more than indicate a few special tests by means of which the more common adulterants may be detected.

*Petroleum distillates.* Indicated by: odour, insolubility and distillation tests; low refractive index and Sp. Gr. stability to fuming nitric acid, concentrated sulphuric acid, potassium hydroxide, etc.

*Turpentine oil.* Indicated by: odour, insolubility, optical rotation (especially of first 10% fraction); low B.Pt.; and formation of hydrochloride, M.Pt. 125°C., and nitroso chloride, M.Pt. 103°C.

*Fixed animal and vegetable oils.* Indicated by: high residue on evaporation; insolubility (except castor oil); increase of ester value; decomposition on heating (acrolein odour).

*Fatty acids.* Indicated by high acid value.

*Cedarwood, copaiba, and Gurjan balsam oils.* Indicated by: high B.Pt., Sp. Gr., and refractive index; abnormal optical rotation; solubility. Gurjan balsam oil gives an intense violet coloration when a few drops of conc. nitric acid are added to an acetic acid solution.

*Alcohol, acetone, and chloroform.* Indicated by: low B.Pt. and refractive index; odour. Alcohol may be detected and approximately estimated in otto of rose by noting the increase of refractive index after washing with water.

*Resins* (especially in Cassia oil). Indicated by: dark colour; precipitate with lead acetate solution; high non-volatile residue; high acid value.

*Terpenes.* Indicated by: general lowering of the quality of the oil; low Sp. Gr. and refractive index; solubility; and generally by high optical rotation.

*Artificial esters, etc.* (especially in bergamot and lavender). These are often difficult to detect; the general characteristics of the oil frequently give no indication of the addition. The following adulterants have been found: glyceryl acetates, terpinyl acetates, ethyl and methyl esters of acetic, citric, tartaric, oxalic, succinic, benzoic, lauric, oleic, and phthalic acids; fatty oils and acids.

The best method for the detection of added esters is

generally to isolate the acids and identify them; the commonly naturally occurring acids are acetic, butyric, valeric, and caprylic, and occasionally benzoic and salicylic. Glyceryl and terpynyl acetates, etc., may be detected as follows:—

**Glyceryl acetate.** 10 cc. of the oil are shaken with 20 cc. of 5% alcohol, separated, and the aqueous layer filtered to clearness, exactly neutralised with N/10 alkali, and the ester value estimated; 0.6 cc. of N/2 alkali represents 1% of glyceryl acetate; an allowance of about 0.2 cc. must be made for the amount of pure oil dissolved. As confirmatory tests, the refractive index and ester value of the washed and dried oil may be compared with those of the original sample. Glyceryl acetate elevates both these figures. The refractive index of glyceryl triacetate is  $\mu_D^{15}$  1.4328; 1% elevates the apparent linalyl acetate content of bergamot or lavender oil by 2.62%.

**Terpynyl acetate.** This may sometimes be detected by its odour. It is estimated by a process of fractional hydrolysis, advantage being taken of the fact that terpynyl acetate is more slowly hydrolysed than is linalyl acetate. The ester values obtained after boiling for 30 mins. and 2 hrs. with N/2 alcoholic caustic alkali should not differ by more than one unit with pure oils, but the presence of each 2% of terpynyl acetate causes approximately a difference of one unit.

Artificial esters of non-volatile acids, such as oxalates, citrates, tartrates, phthalates, etc., may be detected by steam distilling to exhaustion, with a sufficiency of sulphuric or phosphorus acid, the solution remaining from the determination of the ester value (sulphuric and not hydrochloric acid must be used for the back-titration). The amount of volatile acid in the distillate is then determined, and should correspond with that indicated by the saponification value. A blank should be run under identical conditions, with the omission of the oil. Example: An oil containing 2% of ethyl citrate yielded a direct saponification value of 109.1, the "volatile acid value" was 92.8; an oil containing 5% of ethyl succinate gave 127.6 and 91.5 respectively.

The following are the more important publications on the subject:—

- E. J. Parry. "The Chemistry of the Essential Oils and Artificial Perfumes." 2 vols.
- Schildermeister and Hoffman. "The Ethereal Oils." 3 vols.
- Allen's "Commercial Organic Analysis." Vol. IV.
- Sydney Young. "Distillation Principles and Processes."
- Heusler-Pond. "The Chemistry of the Terpenes."
- Perfumery and Essential Oil Record.

# Properties of the Essential Oils.

| Name and source.   | Yield per cent. | Constituents.   | Sp. Gr. at 15° C.        | Optical rotation at 20° C. | [Refr. index] <sub>D</sub> at 20° C. | One part soluble in parts alcohol.        | Other data and information.  |
|--|-----------------|---|--------------------------|----------------------------|--------------------------------------|---|--|
| Ajowan oil<br><i>Carum ajowan</i> ,<br><i>Ptychotis ajowan</i>   | 3-4             | Thymol (38-60%),<br>thymene, a mixture of<br>cymene and terpinene.  | 0.910<br>-0.930          | +1° to<br>+5°              | 1.4980<br>-1.5005<br>(35° C.)        | 3 (70%)                                   | Found in India,<br>Persia, Afghani-<br>stan                                    |
| Almond oil, bitter<br><i>Prunus amygdalus</i><br><i>amaru</i> (kernels<br>Peach and apricot<br>kernels with HCN) | 0.5-1           | Benzaldehyde (99%),<br>prussic acid, benzalde-<br>hyde cyanhydrin,<br>Natural oil 2-5% HCN.   | 1.045<br>-1.060<br>1.124 | Inactive                   | 1.542<br>-1.546                      | 2 (70%)                                   | Found in Europe,<br>Asia, N. Africa,<br>California                             |
| Anise oil (Aniseed)<br><i>Pimpinella anisum</i><br>(fruits)  | 2-3             | Anethole (80-90%),<br>methyl chavicol, anisic<br>aldehyde, anisic acid in<br>old oil.   | 0.975<br>-0.990<br>(20°) | 0° to -2°                  | 1.552<br>-1.558<br>(25° C.)          | 3-5 (90%)                                 | M.pt. 17°-20° C.<br>Found in Russia,<br>Germany, France,<br>Spain, Netherlands |
| Anise oil (star)<br><i>Illicium verum</i>  | 3               | Anethole (80-90%), <i>p</i> -cy-<br>mene, <i>d</i> -pinene, <i>l</i> -phellan-<br>drene, methyl-chavicol,<br>anisic aldehyde, anisic<br>acid, cineole, safrole,<br>terpineol, and a sesqui-<br>terpene. | 0.975<br>-0.990<br>(20°) | -2° to<br>+1°              | 1.551<br>-1.558<br>(25° C.)          | 3 (90%)                                   | M.pt. after solidifi-<br>cation 17°-19° C.<br>Found in China<br>and Tonkin     |
| Bay leaves oil<br><i>Pimenta acris</i><br>( <i>Myrcia acris</i> )  | 2-3             | Eugenol, methyl-eugenol,<br>and <i>l</i> -phellandrene, traces<br>of chavicol, methyl chavi-<br>cole, citral, & myrcene.  | 0.950<br>-0.990          | 0° to -3°                  | 1.510<br>-1.520                      | Freshly distil-<br>led, miscible<br>(90%) | Contains phenols<br>(eugenol 50-75%).<br>Found in West<br>Indies               |
| Bergamot oil<br><i>Citrus bergamia</i><br>(peel of fruit)  |                 | Linalyl acetate (35-45%),<br>linalol, limonene, pinene,<br>octylene, camphene, di-<br>pentene, and a stearop-<br>tene of M.P. 188° C.   | 0.881<br>-0.887          | +8° to<br>+20°             | 1.460<br>-1.469                      | 0.3                                       | Found in Calabria.<br>Non-volatile resi-<br>due at 100° C. 5-<br>6%            |
| Cade oil<br><i>Juniperus oxycedrus</i>   | 1.6-3.4         | The sesquiterpene, cadin-<br>ene, B.P. 274-275°.  | 0.995<br>-1.025          | ca. -30°                   |                                      |   | By destructive dis-<br>tillation of the<br>wood                                |

| Name and source.  | Yield per cent. | Constituents.   | Sp. Gr. at 15° C.  | Optical rotation at 20° C.                                     | [Refr. index]p at 20° C.   | One part soluble in parts alcohol.                 | Other data and information.   |
|---|-----------------|---|--|--|--|--|---|
| Cajuput oil<br><i>Melaleuca minor</i> ,<br><i>M. Leucodendron</i> , etc<br>(leaves and twigs)<br>Camphor oil (light)<br><i>Cinnamomum camphora</i> ( <i>Camphora officinalis</i> , <i>Laurus camphora</i> ) (wood)<br>Camphor oil (heavy) |                 | Cineol (Eucalyptol) (45—65%) terpineol, <i>l</i> -pinene; traces of valerio aldehyde and benzaldehyde. Light fractions: Pinene, phellandrene, limonene, dipentene, camphor, cineol, terpineol.<br>Heavy fractions: Safrol, camphor, eugenol, cadinene.<br>Contains a greater portion of sesquiterpenes than ylang ylang oil; esters of benzoic and acetic acids, linalol, geraniol, nerol, farnesol, iso-eugenol, pinene, cresol, para-cresyl methyl ether, cadinene. | 0.917<br>—0.930<br><br>0.860<br>—0.950<br><br>0.950<br>—1.000<br><br>0.906<br>—0.967 | 0° to -4°<br><br>+12° to +32°<br><br>0° to 12°<br>-15° to -87° | 1.460<br>—1.470 (25°C.)<br><br>1.465<br>—1.481<br><br>1.500<br>—1.508<br><br>1.474<br>—1.508 | 3 (80%)<br><br>3 (90%)<br><br>3 (90%)<br>1—2 (90%) | Found in India and Australia. Often contains copper<br>Found in China, Japan and Formosa<br>U.S.A. experimenting on growth of camphor trees<br>First part of rectified distilled oil sold as ylang ylang oil<br>q.v. Sap. val. 40—160, Java variety sap. val. 10—60.<br>Found in Philippines and Malay Archipelago, Islands of Luzon and Java<br>Found in Europe (Holland) and Asia<br>Found in Southern India and Ceylon<br>Ester val. 90—150. |
| Cananga oil<br><i>Cananga odorata</i> (flowers)   | 1.5—2           |   |  |  |  |  |   |
| Caraway oil<br><i>Carum carui</i> (seeds)   | 3—7             | Carvone (50—60%), <i>d</i> -limonene acetaldehyde, piperonal, and methyl alcohol; H <sub>2</sub> S produced during distillation.<br>Cineol, terpineol, limonene, terpinene, sabinene.   | 0.907<br>—0.920 (B.P. minimum 0.910)<br>0.922<br>—0.950                              | +70° to +82° (usually +75° to +78°)<br>+22° to +40°            | 1.484<br>—1.497 (25°C.)<br><br>1.460<br>—1.470   | 10 (80%)<br><br>2—5 (70%)                          |   |
| Cardamom oil<br><i>Elettaria cardamomum</i> (seeds)   | 3.5—8           |   |  |  |  |  |   |

| Name and source.  | Yield per cent. | Constituents.  | Sp. Gr. at 15° C.                  | Optical rotation at 20° C.         | [Refr. index] at 20° C.     | One part soluble in parts alcohol. | Other data and information.   |
|---|-----------------|--|------------------------------------|------------------------------------|-----------------------------|------------------------------------|---|
| Cassia oil<br><i>Cinnamomum cassia</i><br>(leaves, twigs, bark)   | 0.5—2           | Cinnamic aldehyde (75—90%), terpenes, cinnamic esters, phenyl propyl acetate.  | 1.055<br>—1.072                    | +6° to<br>-1°                      | 1.585<br>—1.606             | 3—4 (70%)<br>2 (80%)               | Found in Cochin China, cultivated in China. Often adulterated with resin (10%) Commercial cedar leaf oil often derived from <i>Thuja occidentalis</i> From waste wood |
| Cedar leaf oil<br><i>Juniperus virginiana</i><br>(leaves)   |                 | Limonene, cadinene, bornol, borynl esters.   | 0.883<br>—0.900                    | +55° to<br>+65°                    |                             | Insol. (80%)                       |   |
| Cedar wood oil<br>(Virginian red cedar)<br><i>Juniperus virginiana</i><br>(wood)                        | 2.5—5.0         | Cedrol (8—10%), the sesquiterpene cedrene and the alcohol cedrenol.  | 0.940<br>—0.962                    | -25° to<br>-47°                    | 1.495<br>—1.510             | 10—20 (90%)                        |   |
| Cedrat or Citron oil<br><i>Citrus medica</i> (peel)<br>Celery oil<br><i>Apium graveolens</i><br>(fruit) | 2.5—3           | Limonene, citral (5—6%), dipentene.<br>Terpenes (90%), palmitic acid, guaiacol, the lactone sedanolid, sedanollic acid, sedanonic anhydride (last two are the cause of the odour). | 0.851<br>—0.854<br>0.860<br>—0.895 | +77° to<br>+82°<br>+60° to<br>+80° | 1.4750<br>1.479<br>—1.486   | 10 (90%)                           | Fruit used for candied peel Cultivated in European countries; contains no pinene  |
| Chamomile oil<br>(Roman chamomile)<br><i>Anthemis nobilis</i><br>(flowers)                              | 1               | Angelico and tiglio esters of isobutyl, amyl, and hexyl alcohols, anethenol.<br><br>Blue constituent is a sesquiterpene; B.P. 295—300°   | 0.905<br>—0.920                    | -3° to<br>+3°                      | 1.442<br>—1.465<br>(25° C.) | 6 (70%)                            | Sp. Gr. 0.9798 at 25° Soln. in phosphoric acid is fluorescent. Found in Germany, Great Britain, France, Belgium   |

| Name and source.  | Yield per cent. | Constituents.   | Sp. Gr. at 15° C. | Optical rotation at 20° C. | [Refr. index] D at 20° C. | One part soluble in parts alcohol. | Other data and information.   |
|---|-----------------|---|-------------------|----------------------------|---------------------------|------------------------------------|---|
| Chamomile oil<br>(German chamomile)<br><i>Matricaria chamomilla</i> (flowers) | 0.2—0.5         | Chamomillol $C_{15}H_{18}O$ , tri-chamomillol $C_{15}H_{18}O_2$ , esters of caproic acid, solid hydrocarbon, fufural, umbelliferone, methyl ether.        | 0.920<br>—0.955   | 0°                         | 1.364                     | Freely in 90%                      | Solid at 1°C.   |
| Champaca flower oil<br><i>Michelia champaca</i>                               |                 | Benzyl alcohol, geraniol, linalol and esters, isoeugenol, methyl anthranilate.  | 0.907<br>—0.935   | -12° to -52°               |                           |                                    | Found in Java and Philippines   |
| Champaca wood oil<br>or<br>Guaiacum wood oil<br><i>Bulnesia sarmienti</i>     | 4—8             | Guaiol, M.P. 91°C.  | 0.965<br>—0.975   | -3° to -8°                 | 1.503<br>—1.505 (30°)     | 3—5 (70%)                          | Found in Argentine and Paraguay. Is semi-solid, melts to a liquid at 45°—55°C.          |
| Cinnamon oil<br>(Bark oil)<br><i>Cinnamomum zeylanicum</i>                    | 0.5—1           | Cinnamic aldehyde (55—75%), pinene, cymene, phellandrene, benzaldehyde, cumic aldehyde, nonaldehyde, methyl amyl ketone, and a little eugenol (up to 8%). | 0.943<br>—1.040   | 0° to -3°                  | 1.528<br>—1.591 (25°C.)   | 3 (70%)<br>10 (70%)<br>Seychelles. | Found in Ceylon. Should not give blue colour with ferric chloride in alcoholic solution |
| Cinnamon oil<br>(Leaf oil)  | 0.5—2           | Eugenol (75—90%), saffrol, very little cinnamic aldehyde.   | 1.045<br>—1.065   | -1° to +1°                 | 1.530<br>—1.540 (25°C.)   | 3 (70%)                            |   |
| Citronella oil<br><i>Cymbopogon nardus</i> (grass, etc.)<br>(1) Java          | 0.5—0.7         | Citronellal and geraniol predominate.   | 0.885<br>—0.910   | 0° to -3°                  | 1.465<br>—1.473           | 3—10 (80%)                         | Total acetylisable constituents calculated as geraniol 80—100%.                         |
| (2) Ceylon  | 0.25—1          | Geraniol predominates with citronellal, camphene, etc.  | 0.898<br>—0.920   | 0° to -21° (average -12°)  | 1.478<br>—1.490           | 1—2 (80%)                          | Total acetylisable constituents calculated as geraniol 58—64%                           |



| Name and source.   | Yield per cent. | Constituents.  | Sp. Gr. at 15° C. | Optical rotation at 20° C. | [Refr. index]D at 20° C. | One part soluble in parts alcohol. | Other data and information.                                      |
|--|-----------------|--|-------------------|----------------------------|--------------------------|------------------------------------|--|
| Olive oil  | 14—21           | Eugenol (80—95%), esters of eugenol, methyl alcohol, furfural and caryophyllene.               | 1·044<br>—1·069   | 0° to -2°                  | 1·528<br>—1·540 (25° C.) | 1—3 (70%)                          | Cultivated in the Moluccas, Zanzibar, Pemba, Sumatra, etc.       |
| <i>Eugenia caryophyllata</i> (buds)                      |                 |  | 1·032             |                            | 1·532                    |                                    |  |
| Clove oil (leaf)   | 4—6             | Eugenol (75—93%).  | —1·067            | 0° to -2°                  | —1·539                   | 20 (90%)                           | Found in Seychelles  |
| Copaiba oil (oleo-resin)                                 |                 | Chiefly sesquiterpenes (caryophyllene).  | 0·895<br>—0·918   | -1° to -33°                | 1·493<br>(25° C.)        |                                    | Para and Bahia balsams yield 50—65% oil, others yield 40—50% oil |
| Coriander oil  | 0·1—1           | Coriandrol ( <i>d</i> -linalol), and <i>d</i> -pinene.   | 0·870<br>—0·885   | +7° to +14°                | 1·463<br>—1·476          | 3 (70%)                            | Found in most European countries.                                |
| <i>Corandrum sativum</i> (fruit)                         |                 |  |                   |                            |                          |                                    | Total alcohols 45—55%  |
| Cubebs oil   | 10—18           | Cubeb camphor (M.P. 68—70° C., B.P. 245° C.), dipentene, <i>l</i> -pinene, camphene, cadinene. | 0·910<br>—0·930   | -25° to -42°               | 1·485<br>(25° C.)        | 1—10 (90%)                         | Found in Java and Singapore.                                     |
| <i>Piper cubeba</i> (fruit)                              |                 |  |                   |                            |                          |                                    |  |
| Cumin oil (Roman Caraway oil)                            | 2·5—4·5         | Cuminol (20—35%) cuminaldehyde, cymene.  | 0·900<br>—0·930   | +3° to +8°                 | 1·494<br>—1·510          | 3 (80%)                            | Cultivated in Syria, Morocco, Malta & the East Indies.           |
| <i>Cuminum cyminum</i> (fruit)                           |                 |  |                   |                            |                          |                                    | East India oil, Sp. Gr. 0·893—0·899                              |
| Dill oil   | 2·5—4           | Carvone (30—60%), limonene, phellandrene.  | 0·895<br>—0·918   | +70° to +82°               | 1·477<br>—1·490 (25° C.) | 3 (90%)<br>5—8 (80%)               | Found in Caucasus and Mediterranean countries                    |
| <i>Peucedanum graveolens</i> , <i>Anethum graveolens</i> |                 |  |                   |                            |                          |                                    |  |
| Erigeron oil (Oil of fleabane, or bitter weed)           | 0·26<br>—0·66   | Limonene, terpineol citronellal.   | 0·850<br>—0·890   | +45° to +81°               |                          | 1 (95%)                            | Found in N. Amer. Oil resinifies on keeping                      |
| <i>Erigeron canadensis</i> (herb)                        |                 |  |                   |                            |                          |                                    |  |



| Name and source.   | Yield per cent. | Constituents.   | Sp. Gr. at 15° C. | Optical rotation at 20° C. | [Refr. index] <sub>D</sub> at 20° C. | One part soluble in parts alcohol. | Other data and information.  |
|--|-----------------|---|-------------------|----------------------------|--------------------------------------|------------------------------------|--|
| <i>Eucalyptus</i> oil (leaves)<br><i>Eucalyptus amygdalina</i>   | 1.5—4           | Contains 5—25% cineol, mainly phellandrene, pinene.                                 | 0.855<br>—0.890   | —59° to —75°               | 1.476<br>—1.480                      | 3—10 (70%)                         | <i>Eucalyptus</i> species are indigenous to Australia, New Zealand and Tasmania. Cultivated in Spain, Algeria and California |
| <i>Eucalyptus citriodora</i>                                     | 1—1.5           | Almost entirely citronella (85—90%), no cineol, traces of citronellol and geraniol. | 0.865<br>—0.905   | —1° to +2°                 | 1.454<br>1.467                       | 4—5 (80%)                          | Indigenous to Queensland   |
| <i>Eucalyptus globulus</i> (blue gum)                            | 0.8—1.5         | Cineol (55—70%).  | 0.910<br>—0.930   | 0° to +12°                 | 1.460<br>—1.470                      | 3—4 (70%)                          | Found in Tasmania  |
| Fennel oil<br><i>Foeniculum vulgare</i> (F. oapillaceum) (fruit) | 4—6             | Anethol (50—60%), fenchone (10—15%), M.P. +5 to +6°; dextro-pinene, and dipentene   | 0.960<br>—0.990   | +6° to +24°                | 1.525<br>—1.550                      | 5—8 (80%)                          | Cultivated in France, Italy, Roumania, Germany, India, Japan   |
| Water fennel oil<br><i>Enanthe phellandrium</i> (fruit)          |                 | Phellandrene (70—80%), pinene, sabinene.  | 0.850<br>—0.894   | +2° to +20°                | 1.484<br>—1.495                      |                                    | M.pt. after solidification +3 to +10°C.<br>Useless for flavouring  |

| Name and source.                                      | Yield per cent. | Constituents.                            | Sp. Gr. at 15° C. | Optical rotation at 20° C. | [Refr. index] at 20° C. | One part soluble in parts alcohol. | Other data and information.  |
|---|-----------------|--|-------------------|----------------------------|-------------------------|------------------------------------|--|
| Sweet fennel oil<br><i>F. dulce</i> (fruit)           |                 | High anethol content; no fenchone.       | 0.976<br>—0.980   | +5° to<br>+16° 30'         |                         |                                    | Found in South of France.<br>M.pt. 10—15°C.  |
| Wild bitter fennel oil (herb)                         |                 | No anethol, some fenchone, phellandrene. | 0.910<br>—0.925   | +41° to<br>+48°            | 1.476                   |                                    | Found in France, Spain, Algeria  |
| Galangal oil (Chinese ginger)                         | 0.5—1.5         | Cineol, pinene and eadinene.             | 0.915<br>—0.925   | —1° to<br>—6°              | —1.483                  |                                    | Indigenous to China and Siam   |
| <i>Alpinia officinarum</i> (rhizome)                  |                 |  |                   |                            |                         |                                    |  |
| Geranium oils   |                 |  |                   |                            |                         |                                    |  |
| See Rose geranium oil                                 |                 |  |                   |                            |                         |                                    |  |
| Ginger oil  | 1—3             | Phellandrene, camphene, zingiberene.     | 0.872<br>—0.886   | —25° to<br>—45°            | 1.488<br>—1.495         | Insol. (95%)                       | Indigenous to tropical Asia  |
| <i>Zingiber officinale</i> (rhizome)                  |                 |  |                   |                            |                         |                                    |  |
| Ginger-grass oil                                      | 0.1             | Geraniol (35—70%), geranyl acetate.      | 0.900<br>—0.955   | —30° to<br>+54°            | 1.478<br>—1.495         | 1—3 (70%)                          | Is an inferior kind of Palmarosa oil.  |
| <i>Cymbopogon Martini</i> , var. <i>sofia</i> (grass) |                 |  |                   |                            |                         |                                    | More geranyl acetate than Palmarosa oil. Esters 5—25%  |
| Guaiacum wood oil                                     | 4—8             | Is solid or semi-solid; oil at 45°—55°C. | 0.965<br>—0.975   | —3° to<br>—8°              | 1.503<br>—1.505 (30°)   | 3—5 (70%)                          | Indigenous to the Argentine and Paraguay. Called Holy Wood. An adulterant of rose oil and sandalwood oil |
| <i>Bulnesia sarmienti</i> (Champaca wood oil)         |                 |  |                   |                            |                         |                                    |  |
| Gurjum balsam oil                                     | 45—70           | Chiefly sesquiterpene.                   | 0.915<br>—0.930   | —35° to<br>—130°           | 1.503<br>—1.505         |                                    |  |
| Species of <i>Dipterocarpus</i>                       |                 |  |                   |                            |                         |                                    |  |

| Name and source.   | Yield per cent. | Constituents.   | Sp. Gr. at 15° C.                      | Optical rotation at 20° C.      | [Refr. index] <sub>D</sub> at 20° C. | One part soluble in part alcohol. | Other data and information.   |
|--|-----------------|---|--|---------------------------------|--------------------------------------|-----------------------------------|---|
| <i>Hedeoma</i> oil<br>(American penny-royal)<br><i>Hedeoma pulegioides</i><br>(fresh herb)<br>Hop oil    | 1.5             | Pulegone (30%).   | 0.925<br>—0.960                        | +18° to +35°                    |                                      | 1—3 (70%)                         | Indigenous to N. America  |
| <i>Humulus lupulus</i><br>(flowers)  | 0.3—1           | Dipentene, linalol, geraniol, <i>α</i> -caryophyllene, humulene.  | 0.840<br>—0.872                        | 0° to +1°                       | 1.477<br>—1.490                      | Insol. 90%                        |   |
| Jasmine oil<br><i>Jasminum grandiflorum</i> (flowers)  | 0.004<br>—0.006 | Benzyl acetate (85%), linalyl acetate (7.5%), linalol (16%), benzyl alcohol (6%), <i>p</i> -cresol indole, jasmone, methyl anthranilate.              | 0.920<br>—1.020                        | —1°15' to +4°                   |                                      |                                   | Esters 41—73% as benzyl acetate.  |
| Juniper berry oil<br><i>Juniperus communis</i>   | 1—2             | Pine, cadinene, juniper camphor, a sesquiterpene alcohol, M.P. 165°C., and its esters.  | 0.860<br>—0.890                        | —3° to —20°                     | 1.472<br>—1.488 (25°C.)              | 4 (95%)                           | Found in Hungary, Italy, Juniper wood oil is a mixture of the berry oil with turpentine |
| Kuromoji oil<br><i>Lindera sericea</i><br>(leaves and twigs)<br>Laurel leaf oil<br><i>Laurus nobilis</i> | 1—3             | Linalol (40—50%), 10% esters (geranyl acetate).<br>Cineol (25—50%), geraniol, methyl chavicol, eugenol and esters of isobutyric and valerianic acids. | 0.890<br>—0.915<br><br>0.915<br>—0.936 | —2° to —22°<br><br>—15° to —22° |                                      | 1—4 (70%)<br><br>3 (80%)          | Found in Japan<br><br>Found in Asia Minor and Syria.<br>Ester value 47                  |

| Name and source.   | Yield per cent. | Constituents.   | Sp. Gr. at 15° C. | Optical rotation at 20° C. | [Refr. index] at 20° C. | One part soluble in parts alcohol. | Other data and information.   |
|--|-----------------|---|-------------------|----------------------------|-------------------------|------------------------------------|---|
| 1) English   | 0.8—1.7         | Esters as linalyl acetate (7—10%), linalol, geraniol, nerol.  | 0.879—0.900       | —3° to —10°                | 1.460—1.468 (25° C.)    | 3 (70%)                            | English oil is the most highly valued Highest ester figure for a genuine oil 61.6 Finest oils 35—40% esters Found in France, Spain and Italy. Total alcohols as borneol 25—45%. Esters as linalyl acetate 4—6% Found in S. Italy, Sicily. 1st 10% (vacuum) Opt. Rot. +52° to +60° |
| (2) French   | 0.5—1           | Esters as linalyl acetate (25—45%). Linalol, borneol, camphor, cineol, terpineol, <i>d</i> -camphene. | 0.906—0.922       | —2° to +12°                | 1.462—1.468             | 3 (70%)<br>6 (65%)                 |   |
| Lemon oil<br><i>Citrus limonum</i> (peel)                                  | 0.8             | Limonene (90%), citral (3.5—6%), higher aldehydes, octylic, nonylic, and decylic. Citral (40—50%).    | 0.857—0.862       | +57° to +65°               | 1.473—1.476 (25° C.)    | 10—12 (90%)                        |   |
| Lemon oil (conc.) (terpeneless)  |                 | Citral (60—75%).  | 0.895—0.900       | —5° to —9°                 | 1.479—1.483             | 1—2 (80%)                          |   |
| Lemon oil (sesquiterpeneless)  |                 | Citral (α and β), citronellal, geraniol, limonene, and dipentene.                                     | 0.895—0.905       | —5° to +3°                 | 1.483—1.488             | 3 (70%)                            | Found in Ceylon and Straits Settlements. <i>C. Aezuosus</i> for Malabar and Coochin oil   |
| Lemon-grass oil (Indian verbena oil)<br><i>Cymbopogon citratus</i> (grass) | 0.2—0.26        | Citral (70—80%).  | 0.877—0.887       | —2° to +2°                 | 1.484—1.489             | Insol. (90%)                       |   |
| (1) East Indian  | 0.24—0.4        | Citral (75—85%).  | 0.875—0.895       | —5° to —13°                | 1.459—1.465             | 3 (70%)                            | Found in Mexico   |
| (2) West Indian  | 7—10            | Linalol (55—75%), geraniol, terpinene, methyl heptenone.  |                   |                            |                         |                                    |   |
| Linaloe oil<br><i>Bursera delapachiana</i><br><i>B. ulberylon</i> (wood)   |                 |   |                   |                            |                         |                                    |   |

| Name and source.  | Yield per cent. | Constituents.   | Sp. Gr. at 15° C. | Optical rotation at 20° C. | [Refr. index]D at 20° C.    | One part soluble in parts alcohol. | Other data and information.  |
|---|-----------------|---|-------------------|----------------------------|-----------------------------|------------------------------------|--|
| Lime oil<br><i>Citrus limetta</i><br>(fruit)<br>Hand pressed oil                            |                 | Citral (6—10%), pinene, limonene, dipentene, linalol and ester, a stearoptene.                        | 0.872<br>—0.902   | +30° to +40°               | 1.476<br>—1.485             |                                    | Found in Italy   |
| Distilled oil<br><i>Citrus medica</i> var.<br><i>acidula</i>                                |                 | Practically no citral; pinene, limone, dipentene, cymene and sesquiterpene limene.                    | 0.856<br>—0.868   | +34° to +54°               | 1.470<br>—1.478             |                                    | Found in West Indies and Montserrat  |
| Mace oil (see Nutmeg oil)<br>Marjoram oil<br>(sweet)<br><i>Origanum marjorana</i><br>(herb) | 0.3—0.9         | Terpinene, terpineol, terpin hydrate, borneol, camphor.   | 0.890<br>—0.910   | +15° to +18°               | 1.472<br>—1.478             | 3 (80%)                            | Found in Spain   |
| Matiao oil<br><i>Piper augustifolium</i><br>(leaves)  | 0.5—6           | Matiao camphor (odorous, M.P. 94°), asarone (Sp.Gr. 1.077), terpenene, cineole, apirole.              | 0.938<br>—1.135   | —30° to +6°                | 1.495<br>—1.530             | 10 (80%)                           | Found in tropical America  |
| Mustard oil<br><i>Sinapis nigra</i><br>(seeds)  | 0.5—1.0         | Allyl iso-thiocyanate (90—95%), allyl cyanide, carbon disulphide.                                     | 1.014<br>—1.032   | Inactive                   | 1.525<br>—1.535<br>(25° C.) |                                    |  |
| Neroli oil<br><i>Citrus bigaradia</i><br><i>C. aurantium</i><br>(flowers)                   | 0.08<br>—0.15   | L-Linalol (30%), terpineol, limonene, linalyl acetate (7—20%), methyl anthranilate, indole, terpenes. | 0.870<br>—0.885   | 0° to +45°                 | 1.468<br>—1.477             | 3 (80%)                            | Neroli oil from bitter orange, Bigarade from sweet orange, Found in Portugal |

| Name and source.   | Yield per cent. | Constituents.  | Sp. Gr. at 15° C. | Optical rotation at 20° C. | [Refr. index] <sub>D</sub> at 20° C. | One part soluble in parts alcohol. | Other data and information.  |
|--|-----------------|--|-------------------|----------------------------|--------------------------------------|------------------------------------|--|
| Nutmeg oil (seed)  | 7-15            | Terpenes, alcohols, myristicin (4%).   | 0.865<br>—0.930   | +10° to +30°               | 1.475<br>—1.489<br>(25° C.)          | 3 (90%)                            | Indigenous to the Moluccas, Banda and Sunda Islands                  |
| Mace oil (ex arillus of nutmeg)  |                 |  | 0.890<br>—0.930   | +10° to +20°               | 1.476<br>—1.480                      | 3 (90%)                            | Not more than 5% residue when evaporated on a water-bath             |
| Orange oil   |                 | Limonene (90%), citral, decylic aldehyde, methyl anthranilate, terpineol, linalol. | 0.846<br>—0.852   | +94° to +99°               | 1.472<br>—1.478                      |                                    |  |
| Sweet orange oil<br><i>Citrus aurantium</i> (peel)                       |                 |  |                   |                            |                                      |                                    |  |
| Bitter orange oil<br><i>Citrus bigaradia</i> (peel)                      |                 |  | 0.848<br>—0.856   | +90° to +98°               | 1.472<br>—1.475                      |                                    |  |
| Origanum oil<br><i>Vir. species of Origanum</i> Trieste                  | 2-3             | Carvacrol, cymene.   | 0.946<br>—0.980   | +1° to -1°                 |                                      | 3 (70%)                            | Phenols 60-85%   |
| Smyrna   | 1.4-2.4         |  | 0.895<br>—0.965   | -1° to -15°                |                                      | 3 (70%)                            | Phenols 25-60%   |
| Cyprus   |                 |  | 0.960<br>—0.970   | 0° to +1°                  |                                      | 3 (70%)                            | Phenols 70-85%   |
| Orris oil<br>Iris species (rhizome)                                      | 0.1-0.2         | Myristic acid (85%), irone (5-10%).  | 0.93-0.94         | +12° to +30°               | 1.495                                | 1.5 (80%)                          | A yellow mass M.pt. 44-50° C.; usually 38-45° C. Acid number 213-222 |
| Palma-rosa oil<br>(Indian geranium)<br><i>Cymbopogon Martini</i> (grass) | 1               | Geraniol, acetic and caproic ester, methyl heptenone, dipentene.                   | 0.885<br>—0.899   | -3° to +5°                 | 1.472<br>—1.480                      | 3 (70%)                            | Found in India. Esters 5-11%; total alcohols as geraniol 75-95%      |

| Name and source.   | Yield per cent. | Constituents.   | Sp. Gr. at 15° C. | Optical rotation at 20° C. | [Refr. index] $D_{20}^D$ at 20° C. | 'One part soluble in parts alcohol. | Other data and information.   |
|--|-----------------|---|-------------------|----------------------------|------------------------------------|-------------------------------------|---|
| Parsley oil<br><i>Petroselinum sativum</i> (fruit)       | 2-7             | Apiol (M.P. 30°C., B.P. 249°C.), terpenes.                    | 1.040<br>-1.100   | -5° to -10°                | 1.512<br>-1.525                    | 4-5 (80%)                           | Indigenous to Asia Minor and Mediterranean countries                                  |
| Patchouli oil<br><i>Pogostemon patchouli</i> (leaves)    | 4               | Cadinene (40-45%), patchouli alcohol (M.P. 56°C.).            | 0.950<br>-0.995   | -40° to -68°               | 1.504<br>-1.520                    | 10 (90%)                            | Found in Straits Settlements and West Indies. Sap. val. 4-18; after acetylation 35-80 |
| Pennyroyal oil<br><i>Mentha pulegium</i> (herb)          |                 | Pulegone (75-80%):  | 0.930<br>-0.960   | +13° to +35°               | 1.475<br>-1.486                    | 2-3 (100%)                          | Found in Europe and N. America.   |
| Peppermint oil<br>Species of mentha herb                 | 0.1-0.2         | Menthol, menthyl esters, menthone, pinene, dimethyl sulphide. |                   |                            |                                    |                                     |   |
| (1) English<br><i>Mentha piperita</i>                    | 0.4-1.0         |   | 0.900<br>-0.910   | -22° to -33°               | 1.460<br>-1.465                    | 3-5 (70%)                           | Total menthol 55-70%; esters as menthyl acetate 3-15%                                 |
| (2) American   | 0.1-1.0         |   | 0.900<br>-0.920   | -18° to -33°               | 1.458<br>-1.467                    |                                     | Total menthol 50-65%; esters as menthyl acetate 6-14%                                 |
| (3) Japanese<br><i>Mentha arvensis</i> (undementholised) | 1-1.6           |   | 0.900<br>-0.915   | -30° to -42°               | 1.460<br>-1.468                    |                                     | Total menthol 70-90% (45-60% in dementholised oil) esters as menthyl acetate 3-6%     |
| Petit-grain oil<br>Orange twigs and shoots               | 0.2-0.4         |   |                   |                            |                                    |                                     | Found in S. France, Spain, Algeria.   |



| Name and source.   | Yield per cent. | Constituents.  | Sp. Gr. at 15° C.        | Optical rotation at 20° C. | [Refr. index]D at 20° C. | One part soluble in parts alcohol. | Other data and information   |
|--|-----------------|--|--------------------------|----------------------------|--------------------------|------------------------------------|--|
| European   |                 | Limonene, linalol, geraniol.   | 0.888                    | -1° to -8°                 | 1.462                    | 3 (70%)                            | Esters as linalyl acetate 50-80%   |
| Paraguay   |                 | Pinene, dipentene, camphene, terpineol and geraniol esters.  | 0.884<br>-0.895          | -2° to +5°                 | 1.462<br>-1.465          | 3 (80%)                            | Esters as linalyl acetate 35-65%   |
| Pimento oil (Allspice)<br><i>Pimenta officinalis</i> (fruit)                                     | 3-4.5           | Eugenol (60-80%) and its methyl ether, cineole, phellandrene, caryophyllene.                       | 1.025<br>-1.055          | 0° to -5°                  | 1.525<br>-1.535 (25° C.) | 2 (70%)                            | Indigenous to West Indies  |
| <i>Pinus pumilio</i>   |                 | <i>l</i> -Phellandrene, sylvestrene, cadinene.   | 0.863<br>-0.875          | -6° to -14°                | 1.474<br>-1.48           | 1½-2½ (95%)                        | 5-7% esters; at least 85% over below 200° C.   |
| <i>Abies sibirica</i> (fresh leaves and twigs)   |                 | Bornyl acetate, pinene, camphene, dipentene, phellandrene.   | 0.900<br>-0.930          | -30° to -45°               | 1.470<br>-1.473          | 1 (90%)                            | Found in Russia. Bornyl acetate 30-45%; 90-95% over below 165° C.  |
| <i>Pinus sylvestris</i>  | 0.4-0.6         | <i>d</i> -Pinene.  | 0.868<br>-0.925          | -22° to +7°                | 1.4735                   |                                    | Esters 2-11%.  |
| Red thyme oil (See Thyme oil)<br>Rose oil (Otto)<br><i>Rosa damascena</i> (flowers)<br>Bulgarian | 0.02<br>-0.03   | Geraniol, citronellol, nerol, farnesol, phenyl ethyl alcohol and stearoptene (10-15%), M.P. 34° C. | 0.850<br>-0.860 (30° C.) | -2° to -4° (25° C.)        | 1.460<br>-1.465 (25° C.) | 1.5 (70%)                          | Found in Bulgaria. M.pt. after solidification 18-22° C.; citronellol 30-45%; total alcohols as geraniol 65-75% |
| Rose oil (French)  |                 |  | 0.859<br>-0.874          | -2° to -4° (25° C.)        | 1.460<br>-1.465 (25° C.) |                                    | Total alcohols 80-85%; citronellol 40-45%  |
| Rose geranium oil<br><i>Pelargonium odoratissimum</i> (leaves)                                   | 0.1-0.2         | Geraniol and esters, citronellol, acetic, butyric, valerianic and tiglic acids.                    |                          |                            |                          |                                    | Indigenous to South Africa. Cultivated in France, Spain, Algeria and Reunion (Hourbon)                         |

| Name and source.   | Yield per cent. | Constituents.   | Sp. Gr. at 15° C. | Optical rotation at 20° C. | [Refr. index] <sup>D</sup> at 20° C. | One part soluble in parts alcohol. | Other data and information.  |
|--|-----------------|---|-------------------|----------------------------|--------------------------------------|------------------------------------|--|
| French   |                 | Esters as geranyl tiglate (22-28%), alcohols as geraniol (75%), citronellol, (about 40%). | 0.895<br>—0.905   | -7° to -12°                | 1.461<br>—1.470                      | 3 (70%)                            | Geranyl tiglate 20-30%.  |
| Algerian   |                 |   | 0.890<br>—0.904   | -6° to -12°                | 1.465<br>—1.472                      | 3 (70%)                            | Geranyl tiglate 16-29%; geraniol 75%; citronellol 33%                          |
| Bourbon Reunion  |                 |   | 0.890<br>—0.896   | -8° to -14°                | 1.461<br>—1.470                      | 3 (70%)                            | Geranyl tiglate 20-34%; 80%; citronellol 40%                                   |
| Spanish  |                 |   | 0.886<br>—0.906   | -7° to -11°                | 1.461<br>—1.470                      | 3 (70%)                            | Geranyl tiglate 25-42%; geraniol 70%   |
| Rosemary oil<br><i>Rosemarinus officinalis</i> (leaves)      | 1-2             | Pinene, camphene, cineol, camphor, borneol, bornyl acetate.                               | 0.895<br>—0.920   | -2° to +15°                | 1.466<br>—1.472 (25°C.)              | 10 (80%)                           | Total alcohols as borneol 8-20%; esters as bornyl acetate 1-7%. M.pt. 9°-10°C. |
| Rue oil<br><i>Ruta graveolens</i> (herb)                     | 0.06            | Methyl nonyl ketone (90%), methyl-anthranilate.   | 0.830<br>—0.845   | 0° to +3°                  | 1.430<br>—1.436                      | 3 (70%)                            |  |
| Sage oil<br><i>Salvia officinalis</i>                        | 1.5-3           | Pinene, cineol, borneol, salvone (thujone).   | 0.910<br>—0.932   | +2° to +25°                | 1.457<br>—1.469                      | 2 (80%)                            | Esters 2-6%; total alcohols 20-25%; salvone (thujone) 40-50%                   |
| Sandal wood oil<br><i>Santalum album</i> (wood)              | 2.5-6           | Santalol (90-98%), sesquiterpenes and alcohols.   | 0.973<br>—0.985   | -13° to -21°               | 1.500<br>—1.510                      | 6 (70%)                            | Found in India. Sap. val. 5-20.  |
| Sassafras oil<br><i>Sassafras officinale</i> (root and bark) | 3-9             | Safrol (80-90%), pinene, phellandrene, camphor (6%), eugenol, and cadinene.               | 1.065<br>—1.095   | +1° to +4°                 | 1.525<br>—1.530                      | 2 (90%)                            | Found in N. America, Canada  |

| Name and source.   | Yield per cent. | Constituents.  | Sp. Gr. at 15° C.                  | Optical rotation information. | [Refr. index] <sup>D</sup>        | One part soluble in parts at 20° C. | Other data and alcohol.                     |
|--|-----------------|--|------------------------------------|-------------------------------|-----------------------------------|-------------------------------------|---|
| Savin oil<br><i>Juniperus sabina</i>   | 3-5             | Pinene, sabinene, sabinol (free, 10%), sabinyl acetate (36-55%).<br>Linalol. | 0.910<br>-0.930                    | +40° to +60°                  | 1.472<br>-1.477                   | 15 (80%)                            | A Japanese oil; total alcohols 65-90%       |
| Shiu oil   |                 |  |                                    |                               |                                   |                                     | Found in America and Germany                |
| Spearmint oil<br><i>Mentha viridis</i> , <i>M. Crispa</i> (fresh herb)             | 0.3             | Carvone (35-66%), limonene, pinene, and esters.                              | 0.870<br>-0.895<br>0.920<br>-0.940 | -1° to -16°<br>-30° to -52°   | 1.4606<br>1.480<br>-1.489 (25°C.) | 1-1.5 (80%)                         |   |
| Spike Lavender oil<br>(See Lavender oil)   |                 |  |                                    |                               |                                   |                                     |   |
| Star anise oil<br>(See Anise oils)   |                 |  |                                    |                               |                                   |                                     |   |
| Sweet Birch oil<br>(Oil of winter-green)   | 0.5-0.7         | Methyl salicylate (99%).   | 1.180<br>-1.187                    | Inactive                      | 1.534<br>-1.537                   | 5-8 (70%)                           | Indigenous to S. Canada and Northern U.S.A. |
| <i>Betula lenta</i><br>(bark, etc.)  |                 |  |                                    |                               |                                   |                                     |   |
| Tansy oil<br><i>Tanacetum vulgare</i> (herb)                                       | 0.1-0.2         | Thujone (tanacetone), <i>l</i> -camphor, borneol.                            | 0.925<br>-0.955                    | +25° to +45°                  | 1.457<br>1.460                    | 4 (70%)                             |   |
| Tarragon oil<br>(Estragon oil)   |                 | Estragol (methyl chavicol), phellandrene.                                    | 0.890<br>-0.960                    | +2° to +9°                    | 1.516<br>-1.578                   | 10 (80%)                            | Indigenous to Siberia                       |
| <i>Artemisia dracunculus</i>   |                 |  |                                    |                               |                                   |                                     |   |
| Thyme oils   |                 |  |                                    |                               |                                   |                                     |   |
| Red Thyme oil<br><i>Thymus-vulgaris</i> (herb)                                     |                 | Thymol, carvacrol, <i>γ</i> -mene, <i>l</i> -pinene, borneol, linalol.       | 0.905<br>-0.930                    | 0° to -4°                     | 1.480<br>-1.498                   | 2 (80%)                             | Found in S. France<br>Phenol content 20-50% |
| Lemon Thyme<br><i>Thymus hyemalis</i>  |                 | Carvacrol, citral (10%).   | 0.900                              |                               |                                   |                                     | Spanish; phenol content 8-12%               |
| Turpentine oils  |                 |  |                                    |                               |                                   |                                     | 80-85% distilla                             |
| Species of Pinus   |                 | <i>d</i> - or <i>l</i> -pinene.  | 0.855<br>-0.877                    |                               | 1.465<br>-1.480                   | 5-8 (70%)                           | 155-165°C.;<br>Iodine value 360-375 (Wije)  |
| American<br><i>Pinus australis</i><br>( <i>Pinus palustris</i> , <i>P. taeda</i> ) |                 |  | 0.862<br>-0.870                    |                               | 1.468<br>-1.473                   |                                     | 95% below 170°C.                            |

| Name and source.  | Yield per cent. | Constituents.   | Sp. Gr. at 15° C.                  | Optical rotation at 20° C.        | [Refr. index] D at 20° C. | One part soluble in parts alcohol. | Other data and information.   |
|---|-----------------|---|------------------------------------|-----------------------------------|---------------------------|------------------------------------|---|
| French<br><i>Pinus maritima</i><br>Russian and<br>Swedish<br><i>Pinus sylvestris</i><br>Wood turpentine<br>(Yellow pine oil)<br>(Stumps of felled trees)  | 15-16           | Total alcohols (50%), terpineol, borneol, isofenchyl alcohol, pinene, camphene, etc.<br>Citral (20-38%),<br>linonene, geraniol. | 0.855<br>-0.874<br>0.855<br>-0.874 | -18° to<br>-40°<br>+5° to<br>+16° | 1.470<br>-1.480<br>1.479  | 5-8 (70%)                          | 75-90% distills<br>155-165° C.;<br>30-70% distills<br>155-165° C.;              |
| <i>Verbena</i> oil<br>(true Vervain oil)<br><i>Verbena officinalis</i> ,<br><i>V. triphylla</i><br>Vetiver oil<br><i>Vetivera zizanioides</i><br>(dried root)                                       | 0.4-1.0         | Sesquiterpenes.   | 0.900<br>-0.920<br>0.982<br>-1.042 | -8° to<br>-16°<br>+10° to<br>+40° | 1.515<br>-1.530           | 3 (80%)<br>3 (80%)                 | Found in France<br>and Spain.<br>Found in Mysore,<br>Bengal, Burma,<br>Reunion. |
| Wintergreen oil<br>(See Sweet birch oil)<br>Wormseed oil<br>(1) American<br><i>Chenopodium</i><br><i>ambrosioides</i><br>(2) European<br><i>Artemisia maritima</i><br>Wormwood oil,<br>Absinthe oil | 0.6-1<br>2      | Paraoymentene (20%), ascaridol (60-65%), sylvestrene, camphor.<br>Thujone, cineol, dipentene, terpinene, terpineol.             | 0.950<br>-0.990<br>0.915<br>-0.940 | -5° to<br>-10°<br>0° to -5°       | 1.466<br>-1.476           | 4-10 (70%)                         | Chenopodium oil<br>Sap. val. 246-280  |
| <i>Artemisia</i><br>Wormwood oil,<br>Absinthe oil   | 0.2-0.97        | Thujone, thujyl alcohol esters of acetic, isovaleric, and palmitic acids, pinene.   | 0.925<br>-0.955                    | Dextro                            | 1.460<br>-1.474           | 2-4 (80%)                          | Found in Africa,<br>Europe, N. Asia.  |
| <i>Artemisia</i><br><i>absinthium</i> (herb)<br>Ylang Ylang oil<br><i>Cananga odorata</i><br>(flowers)<br>(See Cananga oil)   | 1.5-2           | Esters of benzoic and acetic acids, alcohols, phenols, and sesquiterpenes.  | 0.930<br>-0.967                    | -38° to<br>-65°                   | 1.480<br>-1.515           | 1-2 (95%)                          | Sap. val. 95-160.   |

## PAINTS AND PIGMENTS.

### Analysis of Pigments.

#### WHITE PIGMENTS.

*White lead.* When pure, this has a composition approximating to  $2\text{PbCO}_3 \cdot \text{Pb(OH)}_2$ . The following determinations are carried out :

Moisture, by heating at  $105^\circ\text{C}$ . Water of combination is usually determined by difference; it may be estimated by heating at  $150^\circ\text{C}$ . for 6—8 hours, but the result is usually high owing to loss of carbon dioxide.

Total lead is determined either (i) volumetrically or (ii) gravimetrically.

(i) About 0.5 gm. of the white lead is dissolved in nitric acid, excess ammonia is added, and the solution made distinctly acid with acetic acid. It is then boiled, and sufficient standard potassium dichromate added to precipitate almost the whole of the lead. The solution is boiled until the precipitate changes in colour from yellow to orange, and whilst still boiling, the titration is completed, using a  $2\frac{1}{2}\%$  solution of silver nitrate as external indicator. The dichromate is usually of such a strength that 1 cc. = .01 gm. Pb, and is standardised against pure lead.

(ii) About 1 gm. of the white lead is moistened with water, dissolved in acetic acid, filtered and washed. The residue is ignited, and weighed as impurity ( $\text{BaSO}_4$ , etc.). The filtrate is treated with sulphuric acid, and evaporated until all acetic acid has been removed, and further until white fumes are evolved. The total lead is then estimated as sulphate in the usual manner.

Sulphate is estimated by dissolving a quantity of the white lead in a slight excess of hydrochloric acid, diluting to 200 cc., and filtering. The lead is deposited by means of aluminium foil held on the bottom of the beaker whilst the solution is gently boiled. The solution is filtered, the filtrate oxidised with a few drops of bromine water, boiled to expel excess of bromine, and the sulphate present is then precipitated as  $\text{BaSO}_4$  and is calculated to  $\text{PbSO}_4$ .

Carbonate. Carbon dioxide is liberated from the pigment either by heating alone or with hydrochloric acid, and is dried, collected in caustic potash, and weighed. The carbon dioxide is calculated to  $\text{PbCO}_3$ , and this, together with the  $\text{PbSO}_4$ , is deducted from the total Pb, the remainder being calculated to  $\text{Pb(OH)}_2$ .

Acetic acid is an objectionable impurity, which it is sometimes necessary to estimate.

To 18 grm. of white lead, contained in a 500 cc. flask fitted for steam distillation, are added 40 grm. syrupy phosphoric acid, 18 grm. zinc dust, and 50 cc. water, and the mixture is distilled to a small bulk by direct heat. Steam is passed in until the flask is half full of condensed water, and the contents of the flask are again distilled to small bulk. This operation is repeated, and the distillate is transferred to another flask, made slightly acid with 1 cc. of phosphoric acid and distilled to small bulk. Steam is passed in and the distillation continued as before, the process being repeated until the distillate is no longer acid. The distillate is titrated, either in bulk or as each 200 cc. distils over, with N/10 alkali, using phenolphthalein as indicator.

*Zinc-lead pigments.* These pigments are made by "subliming" the various grades of zinc-lead ores. The usual names and approximate compositions are —

|                      | % PbSO <sub>4</sub> . | % PbO. | % ZnO. | % ZnSO <sub>4</sub> . |
|----------------------|-----------------------|--------|--------|-----------------------|
| Sublimed white lead  | 75—80                 | 15—20  | 5      | —                     |
| Zinc lead white..... | 50                    | —      | 50     | —                     |
| Leaded zinc white... | 20—25                 | —      | 70—75  | <1.5                  |

The following determinations are made : —

Moisture at 105°C.

Soluble sulphate. The pigment is boiled with aqueous alcohol (3 : 1), filtered, washed, the filtrate boiled to remove alcohol, and the sulphate determined, and calculated to ZnSO<sub>4</sub>.

Total sulphate. The pigment is dissolved in hydrochloric acid, filtered, and sulphate estimated in the filtrate. If much lead is present the estimation is conducted as under "White lead." The sulphate found as ZnSO<sub>4</sub> above is deducted from this value, and the remainder calculated to PbSO<sub>4</sub>.

Lead oxide. Total lead is determined as under "White lead," the lead found as PbSO<sub>4</sub> is deducted from this, and the remainder calculated to PbO.

Zinc oxide. The filtrate from the preceding determination is neutralised with ammonia, 3–5 cc. concentrated hydrochloric acid added, and the zinc estimated volumetrically by means of potassium ferrocyanide solution (see "Volumetric Analysis" Section).

From the amount of zinc found by this test, the Zn present as ZnSO<sub>4</sub> is deducted and the remainder calculated to ZnO.

*Zinc oxide.* Moisture at 105°C.

Soluble sulphate. About 10 grm. of the zinc oxide are extracted with boiling water, filtered, and the sulphate



estimated gravimetrically, or the zinc volumetrically, and calculated to  $\text{ZnSO}_4$ .

Total sulphate is determined as under "Zinc-lead pigments." Total sulphate—soluble sulphate=lead sulphate.

Lead is determined by dissolving in nitric acid, and precipitating lead as sulphate. It may also be determined by precipitating the lead from a slightly acid solution by means of sulphuretted hydrogen, dissolving the lead sulphide in nitric acid, and estimating the lead volumetrically. From the amount of lead found in this test, the lead found as lead sulphate is deducted, and the remainder calculated to  $\text{PbO}$ .

Zinc is determined volumetrically in 0.3 grm. sample dissolved in 8–10 cc. of hydrochloric acid. The zinc present as sulphate is deducted from this value, and the remainder stated as  $\text{ZnO}$ .

Sulphur dioxide is an objectionable impurity which sometimes has to be estimated. 3 grm. sample is mixed with 100 cc. recently boiled and cooled water, and 5 cc. concentrated sulphuric acid added. This is stirred until the solid has dissolved, allowed to stand for 15 minutes, and the sulphur dioxide is determined by means of N/100 iodine solution, using starch solution as indicator.

1 cc. N/100 iodine solution = 0.00032 grm.  $\text{SO}_2$ .

Arsenic and antimony may be estimated by the ordinary analytical methods.

*Lithopone.* Lithopone usually has a composition approximating to:— $\text{ZnS}$ , 27–28%;  $\text{BaSO}_4$ , 70–71%;  $\text{ZnO}$ , 1–1.5%.

The following determinations are usually made:—

Moisture at 105 °C.

Barium sulphate. 1.5 grm. of the sample are boiled with 10 cc. hydrochloric acid and water, and filtered. The residue is washed, and weighed as  $\text{BaSO}_4$ . This may contain silica or clay (see "Analysis of Barytes").

Zinc. The total zinc may be estimated volumetrically in the filtrate from preceding test.

Zinc oxide. 1.5 grm. of the sample are digested for one hour with excess cold 5% acetic acid (about 100 cc. is usually required), the insoluble matter is filtered off and washed, and zinc is estimated volumetrically in the filtrate (after boiling with hydrochloric acid to free from acetic acid), and calculated to  $\text{ZnO}$ .

Zinc sulphide. The insoluble matter from the previous test is boiled with 10 cc. of hydrochloric acid, and zinc is estimated volumetrically and calculated to  $\text{ZnS}$ .

An alternative method of analysis is to oxidise the lithopone with hydrochloric and nitric acids, and weigh the residue as



$\text{BaSO}_4$ . The sulphate in the filtrate is then estimated, and calculated to  $\text{ZnS}$ . In the resulting filtrate the total zinc is estimated, and from this is subtracted the zinc found as  $\text{ZnS}$ , the remainder being calculated to  $\text{ZnO}$ .

#### INERT PIGMENTS.

The analysis of the inert pigments presents no special difficulties, and may be dealt with according to the usual methods. The following outlines are suggested:—

*Barytes, Blanc fixe,  $\text{BaSO}_4$ .* Estimations are made of moisture, loss on ignition, soluble and insoluble in hydrochloric acid (1 : 1). The insoluble matter contains the barium sulphate, together with any silica or silicates, and is therefore fused with fusion mixture and the melt extracted with water and filtered, the residue being washed until free from sulphate. In the filtrate silica, sulphate, alumina and magnesia are estimated. The residue is dissolved in dilute hydrochloric acid (if much silica is present, a portion of it will be present here and must be estimated), and iron, barium, and calcium estimated. If barium is in excess of sulphate, barium carbonate is present, or *vice versa*, other sulphates are present. The magnesia and alumina represent asbestine and kaolin (see later), and any excess silica is free silica. Calcium is calculated to sulphate. If any carbonate is present, it is calculated as  $\text{CO}_2$ , unless there is no doubt as to whether it is barium or calcium carbonate. In case only barium sulphate and silica are present, the latter may be removed by means of hydrofluoric acid.

*Calcium pigments. Paris white, Whiting, Gypsum.* Estimations are made of the moisture, loss on ignition, carbonate, insoluble in dilute hydrochloric acid (barium sulphate and silica), and soluble in dilute hydrochloric acid (iron, alumina, calcium, magnesium, and sulphate).

Magnesium is calculated to sulphate (in gypsum) or to carbonate (in carbonates), the remaining sulphate and carbonate to  $\text{CaSO}_4$  and  $\text{CaCO}_3$ . Loss on ignition *minus* carbon dioxide equals combined water.

*Kaolin* (aluminium silicate). The material is fused with alkali carbonates, and in the melt estimations are made of silica, iron *plus* alumina (gravimetrically), iron (volumetrically), and calcium.

Calcium is calculated to carbonate if carbon dioxide is present, otherwise to oxide.

*Asbestine* (magnesium silicate). This is fused with alkali carbonates, and in the melt are estimated silica, iron and alumina, magnesium, and oxides of potassium and sodium.

*Silica.* This is examined as for insoluble matter under “Barytes.”

## RED PIGMENTS.

Iron oxide pigments include :—

*Indian red*, which is practically pure ferric oxide, with a small amount of insoluble matter, moisture, and combined water.

*Tuscan red*, which contains 40—60% ferric oxide, insoluble calcium salts, water, etc. It is sometimes "brightened" by precipitating upon it an organic red dyestuff.

*Venetian red*, which contains over 70% of ferric oxide, together with insoluble calcium and magnesium salts.

*Ochres*, which, although different in colour, have a composition somewhat similar to the above. They contain about 50—60% silica, 20—25% ferric oxide, 10—15% alumina, and water.

The following determinations are carried out :—

Moisture at 105°C.

Combined water. The residue from the previous test is transferred to a platinum crucible and heated on the blow-pipe to constant weight.

Silica and barium sulphate. The sample is fused with potassium bisulphate, and the melt extracted with water containing a small amount of hydrochloric acid. The insoluble matter is usually silica, but may also contain barium sulphate, and should be treated as under "Barytes."

Iron. The acid solution from the previous test is diluted to a known volume, sufficiently large to keep calcium sulphate in solution, and an aliquot portion titrated for iron, which is expressed as  $\text{Fe}_2\text{O}_3$ .

Alumina. Ferric and aluminium oxides are estimated together in the usual manner in another portion of the sample. From this the amount of  $\text{Fe}_2\text{O}_3$  found in previous test is subtracted, and the remainder expressed as  $\text{Al}_2\text{O}_3$ .

In the filtrate from the alumina test, calcium, magnesium, and sulphate are estimated, and returned as  $\text{CaO}$ ,  $\text{MgO}$ , and  $\text{SO}_3$ .

Carbon dioxide is estimated in the original sample, if necessary, and is deducted from the loss on ignition, and the remainder expressed as combined water *plus* organic matter.

*Red lead* and *Orange mineral*, approximately  $\text{Pb}_3\text{O}_4$ .

The following determinations are made :—

Moisture at 105°C.

Total lead. The sample is dissolved in nitric acid, and the lead estimated either as sulphate or volumetrically. In an impure sample, the acid solution is neutralised with ammonia, made faintly acid with hydrochloric acid, and the lead precipitated as sulphide. This is filtered off, washed, dissolved in nitric acid, and the lead estimated as above.

**Lead dioxide.** 0.5 gm. of the sample are mixed with a solution of 15 gm. sodium acetate crystals and 1.2 gm. potassium iodide in 5 cc. water and 5 cc. 50% acetic acid, and well shaken until all the red lead has dissolved. 15 cc. water are added, and the solution titrated with N/10 thio-sulphate, using starch solution as indicator.

1 cc. N/10 thiosulphate = 0.011955 gm.  $\text{PbO}_2$ .

An alternative method is to triturate 2 gm. of the pigment with 2.5 gm. of ferrous ammonium sulphate, and brush into a beaker. 10—15 gm. ammonium chloride, and 60—80 cc. hydrochloric acid (1:1) are added, the mixture warmed, and excess ferrous iron titrated with N/10 potassium dichromate solution, using potassium ferricyanide as external indicator.

1 cc. N/10 dichromate = 0.011955 gm.  $\text{PbO}_2$ .

Organic matter is usually determined by difference.

*Vermilion* (mercury sulphide). As a pure pigment this is very expensive, and is rarely used, but it has been largely adulterated and imitated.

2 gm. pigment are ignited to constant weight in a porcelain crucible in a draught chamber. The ash should not exceed 0.5%.

Mercury may be estimated, if necessary, by the usual methods.

*Adulterants and substitutes* (vermillionette, etc.). These are usually organic reds on a basis of red lead, zinc oxide, barytes, etc., which may be analysed as usual, estimating organic matter by difference.

The colours mostly used are Paranitraniline red, Alizarin, Eosin, Scarlet 2R, etc., which may be detected qualitatively (see "Identification of Dyestuffs" Section).

#### BROWN PIGMENTS.

*Vandyke brown.* This pigment usually contains about 90% organic matter and water, the remaining ash containing silica, iron, alumina, calcium, etc., which are estimated as under "Iron oxide reds."

*Umbers and Siennas.* Umbers usually contain varying proportions of combined water, silica, and ferric oxide, together with a small amount of moisture, alumina, calcium, manganese, and magnesium salts. Siennas contain varying proportions of combined water, silica, ferric oxide, and manganese dioxide, together with a small amount of moisture, aluminium, calcium and magnesium salts.

The following determinations are made:—

Moisture, combined water, barium sulphate and silica, ferric oxide, alumina, calcium oxide, magnesium oxide, and sulphate, as under "Iron oxide reds."

**Manganese.** A convenient weight of the sample is dissolved in the least possible amount of boiling strong hydrochloric acid, dilute sulphuric acid added, and the solution boiled until white fumes are evolved. The residue is taken up with water, and transferred to a measuring flask. Zinc oxide is added in excess in the form of a paste until all iron present is precipitated. The mixture is made up to volume, allowed to settle, and an aliquot portion treated with bromine to precipitate manganese. The precipitate is filtered off, washed, ignited, and weighed as  $Mn_3O_4$ , being calculated as  $MnO_2$ .

#### BLUE PIGMENTS.

*Prussian blue, Antwerp blue, Chinese blue, Turnbull's blue,* etc. All blues of this class are iron, or double iron and sodium, or potassium, salts of hydroferro- or hydroferri-cyanic acids.

The following determinations are made :—

Moisture at  $105^{\circ}C$ .

Insoluble matter. 1 grm. of pigment is ignited at a low temperature until it is completely decomposed. The residue is digested with hydrochloric acid, evaporated almost to dryness, diluted, filtered and the insoluble matter, probably consisting of barium sulphate, silica, etc., weighed.

Iron is estimated volumetrically in an aliquot portion of the filtrate from the previous test, as stated under "Red pigments."

Sodium or potassium. In another portion of the filtrate from the 'insoluble matter' test, iron, aluminium, and calcium oxides are removed and estimated. The filtrate is then acidified with hydrochloric acid and evaporated to dryness to remove ammonium salts, and the residue weighed as alkali salts. This residue is dissolved in water, made up to known volume, and chloride and sulphate are estimated in aliquot portions of the solution.

Chloride is calculated to  $Na_2O$  or  $K_2O$  (whichever is found by qualitative tests) as combined alkali in the pigment. Sulphate is calculated to  $Na_2SO_4$  or  $K_2SO_4$  as impurity.

Total nitrogen is determined by the Kjeldahl-Gunning method on 1 grm. of sample. The percentage of nitrogen is multiplied by 1.86 to give percentage of CN, and the result is expressed as such.

The complete estimation of these blues is seldom required. Usually it is assumed that

% iron  $\times 3.03 =$  % Prussian blue,  
or, more usually, % nitrogen  $\times 4.4 =$  % Prussian blue.  
and  $N \times 1.857 = CN$ .

*Ultramarine* is probably a complex silicate and sulphide of

soda and alumina. The full chemical analysis is rarely required, but the following determinations may be made:—

**Silica.** A convenient weight of the sample is digested with hydrochloric acid, evaporated to dryness, and baked for two hours. The process is repeated, the residue extracted with hydrochloric acid, filtered, and the insoluble matter weighed as silica. It should, however, be tested for barium sulphate, and this, if present, should be estimated as under "Barytes."

Aluminium is precipitated as hydroxide from the filtrate from the silica test. The precipitate is washed, ignited, and weighed as  $\text{Al}_2\text{O}_3$ . In presence of iron, the precipitate is redissolved, and the iron estimated volumetrically.

**Sodium.** The filtrate from the aluminium test is acidified with sulphuric acid, evaporated to dryness, and the residue ignited, and weighed as  $\text{Na}_2\text{SO}_4$ . The result is stated as  $\text{Na}_2\text{O}$ .

**Total sulphur.** 1 grm. of sample is fused with 4 grm. sodium carbonate and 4 grm. sodium peroxide in a nickel crucible. The melt is extracted with water, acidified, filtered, and sulphate estimated in the filtrate.

**Sulphate.** 1 grm. of sample is treated with hydrochloric acid to remove silica, and sulphate is estimated in the filtrate. This value is deducted from the total sulphate found above, and the remainder is calculated to sulphide.

*Cobalt blue* or *Thénard's blue*, which approximates to  $\text{CoO}.\text{Al}_2\text{O}_3$ .

*Smalt*, which is cobalt potassium silicate.

### YELLOW PIGMENTS.

*Chrome yellows.* These colours, including lemon and canary yellows, consist essentially of lead chromate. The lighter shades contain lead sulphate, whilst the darker shades, including scarlet chrome, chrome red, Chinese red, vermilion substitute, and American vermilion, are probably basic chromates.

The following determinations are carried out:—

**Moisture** at  $105^\circ\text{C}$ .

**Insoluble matter.** 1 grm. sample is dissolved in strong hydrochloric acid, the solution diluted and filtered. The residue is washed, ignited, and weighed as insoluble matter. It should be examined for barium sulphate and silica.

**Lead.** The filtrate from the previous test is neutralised with ammonia, acidified with hydrochloric acid, and the lead precipitated as sulphide. The precipitate is dissolved in nitric acid, and the lead determined gravimetrically as  $\text{PbSO}_4$ .



Chromium may be estimated in the combined filtrates from  $\text{PbS}$  and  $\text{PbSO}_4$  in previous test either gravimetrically or volumetrically. In each case the chromate is calculated to  $\text{PbCrO}_4$ .

Lead sulphate is estimated in 1 grm. of the original sample, as under "White lead."

In the absence of calcium,  $\text{SO}_3$  is calculated to  $\text{PbSO}_4$ , and the lead present as  $\text{PbSO}_4$  and  $\text{PbCrO}_4$  is deducted from total lead, the remainder being calculated to  $\text{PbO}$ . In presence of calcium, any carbon dioxide present is calculated to  $\text{CaCO}_3$ , the remaining calcium being calculated to  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ . The  $\text{SO}_3$  present in this must be deducted from total  $\text{SO}_3$  before  $\text{PbSO}_4$  is calculated.

*Zinc yellow* is usually zinc chromate containing a varying amount of zinc oxide. The following determinations are made :—

Moisture at  $105^\circ\text{C}$ .

Insoluble matter. The pigment is dissolved in an excess of cold strong ammonia, and the solution diluted and filtered. The insoluble matter is dried, weighed, and then extracted with hydrochloric acid and examined for the usual adulterants.

Zinc and Chromium. The filtrate from the previous test is boiled with excess of concentrated hydrochloric acid until the colour is completely changed to green. The chromium is then precipitated by means of ammonia, and zinc estimated volumetrically in the filtrate.

Chromium is calculated to  $\text{ZnCrO}_4$ , and the remaining zinc to  $\text{ZnO}$ .

#### GREEN PIGMENTS.

The green pigments in most common use are what are known as "compound greens," i.e. mixtures of yellow and blue pigments, the chief one being

*Chrome green*. This is a mixture of Prussian blue and lead chromate, either prepared separately and mixed in the dry state, or precipitated together. The following determinations are made :—

Moisture at  $105^\circ\text{C}$ .

Insoluble impurities. A weighed quantity of the pigment is ignited gently in a platinum crucible at a dull red heat, until all the blue is decomposed. The residue is treated with hydrochloric acid, and allowed to digest on the steam bath for an hour. The solution is then diluted and filtered, the precipitate being washed, ignited, and weighed as "Insoluble impurities." It consists usually of barium sulphate, clay, and silicates, which may be identified and estimated if necessary.

Lead is precipitated as sulphide from the filtrate from the

previous test. The lead sulphide is dissolved in nitric acid, and the lead estimated as sulphate.

Iron, aluminium, and chromium. The filtrate from the lead sulphide in the previous test is boiled until free from hydrogen sulphide, and made to known volume. To an aliquot portion of this, ammonia is added, and the precipitate is filtered off, washed, ignited and weighed. This is total  $\text{Fe}_2\text{O}_3$ ,  $\text{Al}_2\text{O}_3$  and  $\text{Cr}_2\text{O}_3$ . The precipitate is dissolved in acid, the iron reduced, and estimated volumetrically, being calculated to  $\text{Fe}_2\text{O}_3$ . In absence of aluminium, this may be subtracted from the weight of precipitate above to give  $\text{Cr}_2\text{O}_3$ . If aluminium is present, chromium must be estimated volumetrically as under "Chrome yellow," and this, together with iron found volumetrically, is subtracted from the weight of precipitate above to give the amount of  $\text{Al}_2\text{O}_3$ .  $\text{Cr}_2\text{O}_3$  should be calculated to  $\text{PbCrO}_4$ .

Sulphate. A portion of the sample is ignited and extracted with hydrochloric acid. Lead is removed as under "White lead," and iron by means of ammonia. The solution is then acidified, and sulphate estimated as usual, and calculated to  $\text{PbSO}_4$ . Any Pb in excess of  $\text{PbCrO}_4$  and  $\text{PbSO}_4$  is calculated to  $\text{PbO}$ .

Prussian blue is either calculated from the iron found as above, or from nitrogen estimated by the Kjeldahl method.

Another compound green is a mixture of zinc yellow and Prussian blue or ultramarine, which are estimated as below.

Zinc yellow is extracted with ammonia, and either the loss taken as zinc yellow, or the extract estimated as under "Zinc yellow" Prussian blue is estimated as under "Chrome green."

Ultramarine The insoluble is probably a mixture of ultramarine and impurities. The ultramarine cannot be estimated directly, but may be approximated by comparison with a standard ultramarine, and the residual impurity assumed to be some inert pigment, *e.g.*  $\text{BaSO}_4$ .

*Guignet's green* is a hydrated sesquioxide of chromium, which frequently contains boric acid. The water may be estimated at above  $200^\circ\text{C}$ . Adulteration is rare, so that full analysis is rarely required. The pigment dissolves only in concentrated hydrochloric acid on prolonged boiling, and impurities soluble in dilute hydrochloric acid may be estimated by extraction. Barium sulphate, etc., are estimated by fusing with 5-6 times the weight of a mixture of equal parts of sodium carbonate and peroxide and proceeding as under "Barytes," estimating the chromium volumetrically in an aliquot portion of the aqueous extract.



The other chromium oxide greens are practically pure  $\text{Cr}_2\text{O}_3$ , and may be examined as above.

The copper and copper-arsenic greens are very rarely, if at all, used in paint manufacture. *Rinmann's green* or *Cobalt green*, a compound of oxides of cobalt and zinc, is, however, sometimes met with.

#### BLACK PIGMENTS.

The essential constituent of all black pigments is carbon, either (1) natural as graphite, or (2) produced by burning oil or natural gas to give lamp black or vegetable blacks, or (3) by calcining matter such as bone ivory or refuse.

The following determinations are made :

Moisture at  $105^\circ\text{C}$ ., and

Ash on 2 grm. of sample, as described in "Coal analysis" section.

Carbon is usually determined by difference : moisture *plus* ash (*plus* oil) from 100 per cent.

In some cases, further examination is necessary to classify the black, *e.g.* in the second class mentioned above, some oily matter is usually present, and the third class is distinguished by the ash.

Oil may be estimated by heating 2 grm. of the dry pigment to dull red heat in a platinum crucible with lid, cooling, and weighing the loss as volatile matter or oil. The residue may then be further heated to ash. The oil may also be extracted from 2 grm. of sample with ether in a suitable extraction apparatus.

Ash may be digested with *aqua regia*, diluted and filtered. The solid matter is washed, ignited, and weighed as insoluble matter. If this is high, it may be further examined for presence of silica, barium sulphate and clay as adulterants. The filtrate from the insoluble matter is made to known volume, and in an aliquot portion, calcium and magnesium (and iron, if necessary) are estimated. In another aliquot portion, the phosphoric acid is precipitated by means of ammonium molybdate, the precipitate dissolved from the filter paper with hot dilute ammonia, and the phosphate estimated in the solution as magnesium pyrophosphæ.

Magnesium is calculated to phosphate, the remaining phosphoric acid to calcium phosphate, and the remaining calcium to carbonate.

#### PHYSICAL TESTS.

Colour. Equal weights of the sample and a standard pigment are placed with an equal number of drops of bleached linseed oil on a large glass plate, and thoroughly rubbed out by means of a suitable spatula. The pigments (in oil) are

transferred on to a glass slide and spread evenly at equal thickness, the standard and the sample side by side, so that one edge of the standard touches one of the sample, and the colour judged from both sides of the slide. During this "rubbing out" process a good idea is obtained of the "fineness" of the sample, compared with a standard sample.

Body or opacity of white (base) pigments. This is the same operation as the colour test, but equal weights of a sample of ultramarine are added to each (e.g. 1 grm. white, 50 mgrm. blue). By comparing the shades of blue obtained, the weaker shade will indicate the stronger white pigment.

A more definite idea of the strength of a pigment may be obtained by rubbing out the standard as above, and additions from a known weight of the sample are made to an amount of blue equal to that in the standard, until the same shade of blue is obtained. The weight of the pigment under examination necessary for this is noted. The method of stating the result varies, but the most usual is as follows:—

100 parts standard correspond to 90 parts sample; sample is 10% strong:

100 parts standard correspond to 110 parts sample; sample is 10% weak.

Tinting strength of colours is the converse of the previous test. Equal weights of the same sample of a (base) white pigment (usually zinc oxide) are taken together with equal quantities of linseed oil, and to one is added a certain weight of a standard colour, and to the other an equal weight of the colour under examination, the last weights depending upon the strength of the colour. The colours are treated as in the previous tests, but in this case the stronger shade indicates the stronger colour. A definite ratio of the strengths of the colours may be obtained in a like manner to the previous test, noting the weights of white pigment used to equal weights of the colour, and stating the results as follows:—

Standard required 100 parts, sample required 90 parts, ZnO;  
sample is 10% weak.

Standard required 100 parts, sample required 110 parts, ZnO;  
sample is 10% strong.

### Paint Materials.

#### *Linseed oil.*

Comparisons of the colour, odour, taste, turbidity, separation of sediment on standing, and time of drying are usually made against a standard sample.

Time of drying. This may be carried out roughly by coating two glass plates, 3"×4", one with the oil under

examination, and the other with the standard. The plates are exposed to air and light at the ordinary temperature, and the time is noted when one ceases to be tacky to the touch, as compared with the other.

A more accurate method is to weigh out about 5 gm. of litharge on a tared flat aluminium or glass dish. 0.5 to 0.9 gm. of the sample is dropped on to the litharge, keeping each drop separate, and the dish, etc., weighed again. The dish is then exposed to air and light, but kept free from dust, for 48 hours, when it is re-weighed, and the amount of oxygen absorbed is calculated as percentage on the original weight of oil. The test may also be carried out without regard to time by comparison with a standard sample.

For still more accurate results, the oil is dried on spongy lead, prepared by the action of granulated zinc on lead acetate and subsequent washing with absolute alcohol.

The value given by this test is usually about 16%, slightly lower in the case of boiled oils.

The following tests are essential :—

Specific gravity at 15.5°C., by Westphal balance, should be 0.932—0.938. A low value indicates the presence of fatty or mineral oils, a high value indicates resin oils, as adulterants.

Moisture is determined by heating 5 gm. of oil in an air oven at 105°C. for 45 minutes.

Unsaponifiable matter is determined as under "Oils and Fats," but petroleum ether is generally used for extraction. This figure should be below 1.5% for raw oils, and below 2.5% for boiled oils.

Saponification value, as under "Oils and Fats." The figure should be 189 to 192.

Iodine value, as under "Oils and Fats," using Hanus' solution. The value should be 178 to 190.

Acid value. 10 gm. of the oil are boiled for half an hour with 50 cc. alcohol, cooled, and titrated with decinormal caustic soda. The figure should be less than 6.0.

Flash point. Generally the "open" flash point is required on linseed oils, principally by railway and steamship companies.

A nickel crucible, 60 mm. diameter at the top, 40 mm. at the bottom, and 60 mm. in height, is placed in a hole in the centre of an asbestos board 200 mm. square, so that the bottom of the crucible projects about 25 mm. through the asbestos. A thermometer, reading to 400°C., is suspended above the centre of the crucible, so that the lower end is 10 mm. from the bottom of the crucible. The oil under examination is then poured into the crucible to a depth of 45 mm. The crucible

is heated by a Bunsen burner, so arranged that the rise in temperature of the oil is  $9^{\circ}\text{C}$ . per minute. A gas jet, 6 mm. long, from a mouth blowpipe is used as a test flame. The testing is commenced when the oil reaches  $220^{\circ}\text{C}$ ., and is continued at every rise of  $3^{\circ}\text{C}$ ., the flame being moved slowly across the entire width of the crucible, immediately in front of the thermometer, and 10 mm. above the surface of the oil. The flash point is the lowest temperature at which the vapours above the oil flash and then go out.

The following tests are optional:—

**Fire point.** This is a continuation of the flash point test. The heating is continued until the vapours catch fire and burn over the surface of the oil.

**Viscosity,** as in the "Liquid fuels" section, usually at  $20^{\circ}\text{C}$ .

**Ash** on 20 grm. of sample. This should be below 0.2%.

**Refractive index,** as in the "Oils and Fats" section.

**Free mineral acid,** as in the "Oils and Fats" section.

**Detection of cottonseed oil,** by the magenta test, as in the "Oils and Fats" section.

**Detection of mineral oil,** as in the "Oils and Fats" section. This will also be indicated by a high value for unsaponifiable matter.

**Detection of resin or resin oil** by the Liebermann-Storch reaction, as in the "Soap Analysis" section.

### *Turpentine.*

The following tests are carried out:—

**Specific gravity** should be 0.862–0.875 at  $15.5^{\circ}\text{C}$ .

**Refractive index** should be 1.469–1.474 at  $20^{\circ}\text{C}$ .

**Flash point;** the "closed" flash point is required, generally the standard Able apparatus is used. The test is commenced at  $37^{\circ}\text{C}$ ., and continued at every  $\frac{1}{2}^{\circ}\text{C}$ . The flash point should not be below  $40.5^{\circ}\text{C}$ .

The remaining tests are performed in comparison with a standard sample tested under similar conditions.

**Colour and Odour.**

**Distillation.** 100 cc. are distilled by direct heat, and the initial boiling point and the boiling point at each 10 cc. noted. Steam distillation may be used, the flask being heated to  $80^{\circ}\text{C}$ ., steam passed in, and each 100 cc. of distillate collected separately and allowed to stand. The boiling point is noted for each fraction, and also the volume of turpentine in each 100 cc. of distillate.

**Residue on evaporation.** This test is carried out on the water-bath; the residue should not exceed 2.0%.

**Sulphuric acid test.** 6 cc. of the sample are taken in a thin-walled, stoppered glass tube, graduated to 30 cc. in tenths.

20 cc. sulphuric acid (4 parts concentrated  $\text{H}_2\text{SO}_4$  to 1 part fuming  $\text{H}_2\text{SO}_4$ ) are added, the tube being then shaken, cooled, and allowed to stand. At intervals the volume of the undissolved layer of oil is noted, and compared with the standard. After each reading the tube is well shaken.

If any adulterants are suspected, the specific gravity and refractive index of each fraction of the distillate should be taken, and a portion of each fraction tested for rosin spirits, which will be detected more readily in the first fractions than in the original turpentine. Wood turpentine is indicated by more regular increases in specific gravity and refractive index, also by a high boiling point, and the specific gravity of the last two or three fractions. Turps substitute lowers the specific gravity and flash point, and increases the range of distillation.

**Rosin spirits.** The fractions are mixed with an equal volume of hydrochloric acid, and granulated zinc is added, when the development of a green colour indicates the presence of rosin spirit. An alternative test consists in mixing a few drops of the fraction with a solution of sulphur in carbon disulphide, and phenol in carbon tetrachloride. Bromine vapour is allowed to come into contact with the surface of this solution, when a green colour indicates rosin spirit.

*Turps substitute.* The following tests are made:—

Specific gravity should be 0.75—0.78.

Colour and Odour.

Closed flash point, as under "Turpentine"; generally about 40°C.

Evaporation, as under "Turpentine." This should leave no residue.

Distillation, as under "Turpentine." 75% should pass over between 150°C. and 200°C., and the remainder below 250°C.

The above tests should be compared with those on a standard sample.

**Sulphur.** 100 cc. of sample are boiled for an hour under a reflux condenser with 1 grm. of metallic sodium. The liquid is cooled, and water is added carefully to dissolve the sodium. The aqueous layer is separated, and to it is added a drop of sodium nitroprusside solution when a violet-blue colour indicates the presence of sulphur.

**Benzene.** The sample is mixed with 8 volumes of strong sulphuric acid, and 2 volumes of strong nitric acid, and gently heated for 10 minutes. A smell of "bitter almonds" indicates the presence of benzene in the original sample.



## Analysis of Paints.

### SEPARATION OF PIGMENT AND VEHICLE.

#### *Extraction of vehicle.*

(a) Quantitatively. A hardened filter-paper is folded cylindrically so as to fit into an extraction thimble, and the whole is dried and weighed. 10 to 15 grm. of the well-mixed paint are spread on the filter-paper, which is then folded, placed in the cylinder, and weighed again. The thimble is then transferred to a Soxhlet or other extraction apparatus, and extraction continued until the process is complete. The thimble is dried and weighed, when the loss in weight represents the amount of vehicle present. The solvent is usually ether, but if much water is present, acetone is preferable, and the water is then included in the loss in weight.

(b) Qualitatively. The amount of pigment from the previous test is generally sufficient for analysis, but larger quantities must be used to obtain an analysis of the vehicle. The separation may be carried out in bulk by placing a large quantity of the paint in a stoppered cylinder, and keeping at a constant temperature not exceeding 60°C. When a suitable quantity of vehicle has separated it may be removed by a syphon, or by suction. Bulk separation may also be effected by means of the centrifuge, *e.g.* the Babcock butter tester, the process being quicker if the chamber is heated to about 60°C. by means of steam.

After most of the vehicle has been removed, the residue is repeatedly mixed with a solvent in order to obtain the pigment free from vehicle; with sufficient care this operation may be made quantitative.

### ANALYSIS OF THE VEHICLE.

#### *Separation of the volatile oils, etc.*

The volatile oils are separated either by direct or steam distillation, the latter being preferable. 100 grm. of the vehicle are weighed into a 500 cc. flask, fitted with an inlet for steam, and also with a condenser. The flask is heated to 100°C. in an oil bath, steam passed in, and the temperature gradually raised to 130°C. The distillation is continued

until the whole of the volatile oil is distilled. The distillate is allowed to stand, the water separated and its volume noted, and the oils are weighed. After allowing for the solubility of turpentine in water (0.3—0.4 cc. per 100 cc.), the volatile oil is calculated to percentage on the vehicle.

The residual oil is kept for further examination. In case the amount of vehicle is not sufficiently large to admit of steam distillation, it is placed in a suitable flask connected with a condenser and distilled. The temperatures at which distillation commences, and of each fraction (10% of whole) are noted, but the distillation is not taken above 185°C. This gives an indication of the result which would be obtained if the volatile oil were re-distilled as noted below. The volatile oil is weighed off as before.

*Analysis of the volatile oils.* These will consist of turpentine, rosin spirit, turps substitute, benzol, etc., and may be examined as under "Turpentine" and "Turps substitute" as far as quantity will permit.

*Analysis of the other oils.* In better class paints the oil remaining after the steam distillation is linseed oil together with a solid drier. It is sometimes adulterated with one or more of the following:—Other drying and semi-drying oils, *e.g.* China-wood, corn, cottonseed, fish oils, etc.; rosin and rosin oils; mineral oils. It is examined as under "Linseed oil," with the following conclusions:—

Specific gravity: low, mineral oil or drying oils other than China-wood oil; high, rosin, etc., or excessive oxidation.

Unsaponifiable matter: high, incomplete separation of the volatile oil, *e.g.* last fraction (high B.P.) of a petroleum substitute.

Saponification value: high, cottonseed oil; low, corn oil.

Iodine value: abnormally high, presence of turpentine; low, semi-drying oils. If Hanus method were used, China wood oil would give a high value, whereas with Hübl's method a low value is obtained.

Ash: high, the presence of "driers" in the vehicle.

The ash will contain the bases of such driers, and may be examined for them, but in presence of lead, it is better mix some of the residual oil with turpentine or benzene, acidify, shake the extract with hot water, and examine the solution.



Rosin should be tested for qualitatively, and estimated as in the "Soap Analysis" section.

If the residual oil is from a direct distillation the results obtained by its examination are not very trustworthy. A better method is as follows:—The oil is saponified, and the unsaponifiable matter extracted as usual, when a high value would indicate presence of heavy petrol turpentine, containing a fraction above  $185^{\circ}\text{C}$ . The soap solution is acidified, and the fatty acids collected and dried, when they are examined for molecular weight and iodine values. They are also tested for presence of rosin and rosin oils.

Water is estimated in the original paint, as in the "Oils and Fats" section. 100 grm. of paint and 75–100 cc. of xylene are used, and the apparatus fitted up so that a slow current of air may be drawn through it during the later stages of the distillation. The presence of pigments containing combined water (*e.g.* white lead) causes inconsistent results. It is usual to deduct from the water found the combined water of any white lead present.

#### ANALYSIS OF THE PIGMENT.

The pigment extracted from the paint is dried at  $105^{\circ}\text{C}$ ., weighed, and is then ready for analysis as under "Pigments." The only difficulty lies in the possible combinations of pigments in one paint. The usual combinations are given below, together with the most complicated case, and suggestions for the analysis. The extreme case seldom occurs, and, on the results of a preliminary qualitative examination, the method of analysis may be arranged to suit the special case. For example, a white paint containing no zinc could only contain white lead and sublimed white lead, or if it contained no lead, only zinc oxide and lithopone could be present, with inert pigments in each case. Further, certain combinations are obviously improbable, *e.g.* lithopone and a lead pigment.

Loss on ignition. This test is usually applied to all pigments, and represents combined water, carbon dioxide, or other chemical loss (*e.g.* burning of  $\text{ZnS}$  to  $\text{ZnO}$ ), and organic matter; the last-named may be some vehicle which has escaped extraction.

The following are the pigments likely to be met with in the different colours of paint:—

*White*—all active and inert white pigments; also a small amount of blue, usually ultramarine.

*Red*—all red pigments; in darker shades alone, in lighter shades with a white base; blue (ultramarine), orange chromes, and black.

*Brown*—white base (as above); umbers; siennas; ochres; some reds and yellows; black.

*Blue*—white base; ultramarine or Prussian blue; greens and yellows.

*Yellow*—white base; chrome and zinc yellows; umbers; ochres; some blues and reds.

*Green*—white base; greens; some yellows or blues; ochres; siennas.

*Grey to Black*—white base; blacks; blues; reds; some ochres or yellows.

It will be seen that an accurate estimation of the various pigments in a coloured paint is difficult, if not impossible, so that the object of the analysis must be to obtain a fairly accurate idea of the proportions and compositions of the white base and the principal colours. The secondary colours and their proportions are found when matching the sample on a practical scale.

The following is a scheme for the analysis of the main constituents of a pigment extracted from a sample of paint:—

*White.* As the sublimed zinc-lead pigments occur very rarely in English practice, they are ignored at the commencement of the analysis.

The pigment is boiled with concentrated hydrochloric acid and filtered; it is noted whether any carbon dioxide or hydrogen sulphide is evolved. The insoluble matter may contain barium sulphate, silica, and aluminium or magnesium silicate. The insoluble is fused as usual, and examined for silica, sulphate, aluminium, barium (and calcium), and magnesium. In the filtrate, lead is estimated as sulphate; the filtrate made ammoniacal (to remove iron), made to known volume, and zinc precipitated with hydrogen sulphide. The precipitate is allowed to settle, and in a portion of the clear liquor calcium (and sometimes barium from the carbonate) is estimated. The precipitated zinc sulphide is dissolved in hydrochloric acid, and the zinc estimated volumetrically.

Carbon dioxide is estimated in the usual way on the original pigment, but in presence of zinc sulphide, a large excess of potassium dichromate must be mixed with the pigment before it is placed in the carbon dioxide generator. In the absence of calcium carbonate, carbon dioxide is calculated to white lead. If calcium carbonate is present a portion of the pigment is extracted three or four times with alcohol and nitric acid (1 part conc.  $\text{HNO}_3$  to 9 parts alcohol by volume), stirring and allowing to settle each time. The extracts are

filtered, the calcium present estimated, and calculated to carbonate. Excess carbon dioxide is calculated to white lead; excess calcium is calculated to sulphate.

Zinc sulphate is estimated in the original pigment, as under "Zinc oxide," and zinc oxide as under "Lithopone" (acetic acid method).

Zinc found as sulphate and oxide is deducted from total zinc, and the remainder calculated to sulphide. If lead be present, sulphate is estimated in a hydrochloric acid extract of the pigment, as under "White lead"; otherwise, sulphate is estimated in the ordinary manner. From this value the sulphate present as zinc and calcium sulphates is deducted, and the remainder calculated to lead sulphate. The lead as sulphate and white lead is deducted from total lead, and if the remainder is considerable, and appreciable quantities of lead sulphate are present, it is calculated to  $\text{PbO}$ ; otherwise it is calculated to  $\text{Pb(OH)}_2$  and added to white lead, as variations in the composition of the latter are possible.

In the insoluble matter barium is calculated to sulphate, and the remainder stated as silica, alumina, lime and magnesia. Magnesia may be multiplied by 2.5 and stated as  $\text{MgO.SiO}_2$ , or may be multiplied by three and stated as asbestine (which allows for 3—5% combined water and impurities); alumina may be calculated to  $\text{Al}_2\text{O}_3.2\text{SiO}_2.2\text{H}_2\text{O}$ ; and the remaining silica stated as free silica.

If the above analysis show the presence of the sublimed zinc-lead pigments (by high percentage of  $\text{ZnSO}_4$ ,  $\text{PbSO}_4$  and  $\text{PbO}$ ), it may be augmented by the following tests:—

The pigment is boiled with a considerable excess of neutral ammonium chloride solution, filtered hot, and the precipitate washed with hot dilute ammonium chloride solution. In the filtrate lead, zinc, calcium, and sulphate are estimated. Calcium is calculated to sulphate, and the remaining  $\text{SO}_3$  to lead sulphate. The remaining lead is calculated to  $\text{PbO}$  or  $\text{Pb(OH)}_2$  (see above), and the zinc to oxide. The insoluble matter is treated as in the preceding estimation, lead being calculated to carbonate or white lead (see above), zinc to sulphide, and calcium to carbonate; other constituents as usual. The loss on ignition, *minus* any  $\text{CO}_2$  found and any combined water in white lead (or in gypsum,  $\text{CaSO}_4.2\text{H}_2\text{O}$ , if present), is stated as "Organic matter."

*Red.* In addition to the above tests, the following are also carried out:—After lead has been removed, the solution is oxidised and iron and aluminium are precipitated as

hydroxides, ignited and weighed. The precipitate is re-dissolved, and the iron estimated volumetrically, as under "Iron oxide reds." The filtrate, containing zinc, etc., is proceeded with as before.

If the presence of red lead is suspected, it is estimated as under "Red lead."

Carbon dioxide and any combined water (in white lead, gypsum, etc.) are deducted from the loss on ignition, and the remainder is still stated as "Combined water (in natural red oxide pigments) and Organic matter."

*Brown.* The only difficulty with a brown pigment is the manganese which contaminates the zinc sulphide precipitate, hence the latter is dissolved in caustic soda instead of hydrochloric acid, filtered, the filtrate acidified and zinc estimated as usual.

Manganese is estimated in the original pigment as under "Umbers and Siennas."

*Blue.* Prussian blue is insoluble in hydrochloric acid, and remains in the first insoluble matter. This is ignited to decompose all the Prussian blue, and the residue is boiled with hydrochloric acid until all the iron is dissolved. This is filtered, and the iron estimated in the filtrate and calculated to Prussian blue, or the Prussian blue may be calculated from a nitrogen determination on the original pigment, except in presence of organic nitrogen, *e.g.* from glue or casein in distempers.

A blue paint containing ultramarine will evolve hydrogen sulphide on dissolving in acid, and will also show itself by the presence of aluminium and silica. The quantity of ultramarine present cannot be definitely estimated, the figure usually given being the average of  $\text{SiO}_2 \times 2.5$  and  $\text{Al}_2\text{O}_3 \times 4$ .

*Yellow.* The main difficulty with a yellow pigment is that it may contain iron, aluminium, and chromium together. The analysis may be carried out as under "Chrome green," or by the following method:—The precipitated hydroxides of iron, aluminium and chromium are dissolved in hydrochloric acid, re-precipitated with ammonia, and, without settling, sodium peroxide is added, and the beaker covered. When all the aluminium and chromium have passed into solution, the ferric hydroxide is filtered off, washed, ignited and weighed as  $\text{Fe}_2\text{O}_3$ . The filtrate is made to known volume, and one portion is acidified with acetic acid and the chromium estimated as lead chromate, or volumetrically. In the other portion, the aluminium and chromium are precipitated by acidifying with hydrochloric acid, and then adding ammonia. From this the

chromium found above (and calculated to  $\text{Cr}_2\text{O}_3$ ) is subtracted, and the remainder is  $\text{Al}_2\text{O}_3$ . Preliminary inspection (*e.g.* blackening with ammonium sulphide) will indicate whether the chromium should be calculated to lead chromate or zinc chromate, and this lead or zinc must be taken into account when "placing" the total lead or zinc to the "base" white pigments.

*Green.* These colours are examined as under "Green pigments" (see also previous section).

A preliminary examination is of great assistance in identifying a green colour; thus Prussian blue is fairly stable to hydrochloric acid, and ultramarine is not; whilst the opposite is the case as regards heat. Also, an "ultramarine-chrome yellow" green is impossible, owing to the presence of sulphides in the ultramarine, and lead in the chrome yellow. In absence of chrome yellow and the corresponding blue, any chromium present is calculated to  $\text{Cr}_2\text{O}_3$ , and stated as such.

*Black and Grey.* When the proportion of coloured pigment to white base is small, the colour may be determined by difference. If it is large, the matter insoluble in hydrochloric acid is filtered through a tared filter, washed, dried, and weighed. It is then ignited and weighed, the loss being taken as organic matter (carbon, etc.). The presence or absence of the usual constituents of the ash, in the hydrochloric acid extract, will give an indication of the quality of black used.



# AGRICULTURAL CHEMISTRY.

Sir E. J. RUSSELL, D.Sc., F.R.S., and H. J. PAGE, B.Sc., A.I.C.

## Soil Analysis.

Soil analysis only serves to compare one soil with another, and its whole value is determined by the reliability of the standard against which the soil is to be measured and the degree to which comparisons can be instituted between them. After ascertaining the source of the soil, the position and geological formation, the analyst should direct enquiries to the County Agricultural Expert at the under-mentioned places as to the results of field experiments made on similar soils in the same area, and, further, whether the conditions are sufficiently similar to the soil he is studying to justify him in using the results as standards.

|  |  |
|--|--|
| Armstrong College, Newcastle-on-Tyne .. .. .       | Cumberland, Durham, Northumberland, Westmorland.   |
| Leeds University .. .                              | Yorkshire.   |
| Midland Agricultural College, Kingston, Derby .. . | Derby, Leicester, Lincoln (Lindsay), Notts., Rutland.  |
| School of Agriculture, Cambridge                   | Bedfordshire, Cambridge, Herts., Hunts., Ely, Lincoln (Holland and Kesteven), Norfolk, Northampton, Suffolk (East and West). |
| Wye Agricultural College ..                        | Kent, Surrey, Sussex.  |
| Reading University College ..                      | Berks., Bucks., Hants., Dorset, Isle of Wight, Middlesex, Oxford.  |
| Bristol University .. .                            | Gloucester, Hereford, Somerset, Worcester, Wilts.  |
| Harper Adams College, Newport, Salop .. .. .       | Shropshire, Staffs., Warwick.  |
| Seale-Hayne Agricultural College, Devon .. .. .    | Devon and Cornwall.  |
| Aberystwyth University College                     | Brecon, Cardigan, Carmarthen, Merioneth, Montgomery, Pembroke, Radnor.   |
| Bangor University College ..                       | Anglesey, Carnarvon, Denbigh and Flint.  |

*Sampling.* Owing to the variation in composition of the soil at different depths it is particularly necessary that the sample should always be taken to the same depth and with a tool making a clean vertical cut. A suitable tool consists of a steel tube 2 ins. in diam. and 12 ins. long, with a  $\frac{3}{4}$  in. slit cut lengthwise and all its edges sharpened, fixed on to a suitable

handle. A mark is made 9 in. from the bottom so that the boring process can be stopped as soon as this depth is reached. After withdrawing the tool, the core of soil is removed by a pointed iron rod. Five or six samples should be taken along lines crossing the field so as to get as representative a sample as possible; the whole bulk must then be sent to the laboratory. Samples should not be taken from freshly ploughed or recently manured land. In very stony soils it is easier to use a 2 in. auger, but this does not yield as satisfactory a sample as the tool described. For precautions to be taken in drawing the sample see Russell (*Journ. Bd. of Agric.*, 1916, **23**, 342), and for a discussion of the magnitude of the experimental error see Robinson (*Journ. Agric. Sci.*, 1915, 7).

The soil is spread out to dry, and is then pounded with a wooden pestle and passed through a 3 mm. sieve. The stones and fine earth are weighed separately, and the proportion of stones to 100 parts of fine earth is calculated. Subsequent analytical operations are made on the fine earth. For the determination of the "available" constituents the "fine earth" is used without grinding. For other determinations, 100 grm. or more of "fine earth" is sifted through a 1 mm. sieve. The part retained by the sieve is ground until it will pass through, and the whole mixed.

*Moisture.* 4-5 grm. of the soil are dried at 100°C. until there is no further change in weight.

*Organic matter.* No accurate method of estimation has yet been devised. It is usual to ignite at low redness the sample dried as above. The loss includes organic matter, water not given off at 100°C., and carbon dioxide from the carbonates; allowance may be made for the latter, but not for the combined water. The carbon is sometimes determined either by the ordinary combustion or by some wet combustion method. Methods have also been described for determining "humus," but they have not come into general use. For ordinary purposes it is sufficient to take the loss on ignition as organic matter.

*Total nitrogen.* Kjeldahl's method is almost invariably adopted. About 25 to 30 grm. of soil are ground up finely in an iron mortar; 10 to 15 grm. are heated in a Kjeldahl flask with 20 to 25 cc. of concentrated sulphuric acid for  $\frac{3}{4}$  hr.; 5 grm. of potassium sulphate and then a crystal of copper sulphate are added. The heating is continued until the liquid is straw-yellow. The mixture is diluted when cool, and the liquid decanted, washing the sand by decantation, and the ammonia content estimated.



*Nitrates.* The fresh soil is rubbed through a 3 mm. sieve, and portions of 250 grm. taken for analysis. If possible, the soil should be extracted at once in the moist condition, but if this cannot be done, the soil should be dried by spreading out in a thin layer in an oven at 50–55°C. for 24 hrs. This drying causes the results to be about 2 parts per million higher than with undried soil; but, provided the conditions of drying are kept uniform, comparable results are obtained. If a vacuum oven is available, the soil can be dried at 55°C. *in vacuo* in less than 2 hrs. without appreciable change of nitrate content.

The fresh or dry soil is extracted on a Buchner funnel with hot distilled water in small quantities, using just enough suction to secure a steady dropping from the funnel. By the time 400 cc. have been collected the whole of the nitrate is usually extracted. The extract is made up to 500 cc., and duplicate determinations are made on 200 cc. portions. The solution is gently boiled for 6 hrs. with 10 cc. of 8% caustic soda and 10 cc. of 3% potassium permanganate. More of the latter is added from time to time if required, together with more water. The volume of the liquid is then made up to about 300 cc., 20 cc. of 40% caustic soda and 5 cc. of alcohol added, followed by 3 grm. of powdered Devarda alloy. The flask is immediately connected to a block-tin condenser fitted with a special spray trap (filled with glass beads or quartz fragments), and with a short length of hard glass tubing at its lower end, dipping into N/50 sulphuric acid in the receiver. The heating, which must be very gentle until the initial reaction has moderated, is so regulated that 200 cc. of distillate are collected in 50 mins. The back titration is carried out with N/50 caustic soda, using methyl red as indicator; CO<sub>2</sub> is boiled off when the end point is almost reached, and the liquid cooled, before finally determining the end point. Devarda's alloy always contains a little nitrogen, so that it is necessary to carry out a blank determination with the reagents, and correct the results accordingly.

The older zinc-copper couple method is described by Russell (*Journ. Agric. Sci.*, 1914, **6**, 53). The rapid phenol sulphonic acid method, as used in the United States, is useful when a large number of estimations have to be made and the highest accuracy is not essential (see Lipman and Sharp, *Univ. Cal. Pub. Agric. Sci.*, 1912, **1**, 23–37).

*Ammonia* may be estimated by distilling with magnesia and water under reduced pressure (Russell, *Journ. Agric. Sci.*, 1910, **3**, 233), but more accurate results are given by the aeration method of Matthews, which, however, requires special

apparatus (*Journ. Agric. Sci.*, 1920, **10**, 72). For older methods see Potter and Synder (*Iowa Research Bull.*, No. 17, 1914).

*Carbonates* are determined by measurement of the amount of carbon dioxide evolved on treatment of the soil with acid. Collins' calcimeter (*J.S.C.I.*, 1906, **25**, 518) gives results of sufficient accuracy for most purposes. For more accurate methods see Amos (*Journ. Agric. Sci.*, 1905, **1**, 322), Hutchinson (*Journ. Agric. Sci.*, 1914, **6**, 323), Hall and Russell (*Journ. Chem. Soc.*, 1902, **81**, 81).

*Lime requirement.* Hutchinson and McLennan's method for the determination of the lime requirements of the soil is as follows: 10 to 20 grm. of the soil are placed in a bottle of 500 to 1000 cc. capacity together with 200 to 300 cc. of approximately N/50 solution of calcium bicarbonate, and the air in the bottle is displaced by a current of carbon dioxide in order to avoid possible precipitation of calcium carbonate during the period of the determination. The bottle is then placed in a shaking machine for three hours, after which time the solution is filtered and an aliquot portion of the filtrate is titrated against N/10 acid, using methyl orange as indicator. The difference in strength of this filtrate and that of the initial solution represents the amount of calcium carbonate absorbed, each cubic centimetre of N/10 acid being equal to 5 mgrm. calcium carbonate.

Fisher (*Journ. Agric. Sci.*, 1921, **11**, 19 and 45) has criticised the method, and suggested certain improvements. See also Warth and Saw (*Chemical Mem. Dept. Agric. India*, 1919, **5**, 157-172). There are numerous other methods in existence; for an account of these see Christensen (*Soil Sci.*, 1917, **4**, 115).

*Soil reaction.* The indicator method of determining pH has been applied to soils (see Fisher, *loc. cit.*), but has been found not to be of universal applicability, owing to the disturbing effect of the clay fraction. The electrometric method gives reliable and accurate results, but special precautions and complicated apparatus are needed. A simple and useful test for acid soils is that devised by Comber (*Journ. Agric. Sci.*, 1920, **10**, 420). 2 or 3 grm. of air-dried soil are shaken vigorously in a test-tube with 5 cc. of a saturated alcoholic solution of potassium thiocyanate. A pink or red colour develops at once, or on standing, if the soil is acid. The liquid may be filtered if the colour is faint. This test is not quantitative, but applied to different samples of the same soil,

the degree of acidity, if any, is roughly indicated by the intensity of the red colour. A simplified form of this test, involving the use of aqueous potassium salicylate instead of alcoholic potassium thiocyanate, can be applied directly to the moist soil. (Comber, *Journ. Agric. Sci.*, 1922, **12**, 370).

*Mineral substances.* Complete analysis of a soil after the silicates have been decomposed and the silica volatilised by treatment by hydrofluoric acid is only rarely attempted. The British method, adopted by the Agricultural Education Association, is described as follows by Hall (*The Soil*): 20 grm. of the powdered soil are placed in a resistance-glass flask, covered with about 70 cc. of concentrated hydrochloric acid, and boiled for a short time. The flask is loosely stoppered, and the contents allowed to digest in the water-bath for about 48 hrs. The solution is then cooled, diluted, and filtered. The washed residue is dried and weighed as material insoluble in acid. The solution is made up to 250 cc., and aliquot portions taken for the various determinations. The analytical operations are carried out in the usual manner, but special care must be taken to free the solution from silica or organic matter. Hissink has discussed the value of concentrated hydrochloric acid as a solvent in soil analysis (*Internat. Mitt. Bodenkunde*, 1915, **5**, 1).

As a rule only potash and phosphoric acid are determined, but where other bases are required, they are estimated in the usual way. For determination of iron see Morison and Doyne (*Journ. Agric. Sci.*, 1914, **6**, 97.)

*Potash.*—50 to 100 cc. of the solution are evaporated to dryness, after addition of 0.5 grm. of pure  $\text{CaCO}_3$ , if the original soil did not effervesce on addition of hydrochloric acid, and treated by one of the following methods:

(a) The residue is gently ignited over a Bunsen flame until completely charred, and is then extracted with water until all the potassium chloride has dissolved (Neubauer's method, *Landw. Versuchs. Stat.*, 1905, **63**, 141). The older method due to Tatlock is still sometimes used; it is described by Dyer (*Journ. Chem. Soc.*, 1894, **65**, 115). To the clear filtrate 5 cc. of platinic chloride (containing 0.005 grm. Pt per cc.) are added, and the mixture slowly concentrated on the water-bath to a very small bulk; the potassium platinichloride is filtered off in a Gooch crucible, washed with 80% alcohol, dried and weighed.

(b) 10 cc. of 5% baryta solution are added, the liquid evaporated to dryness, ignited, the residue taken up with

water as in (a); 2.5 cc. perchloric acid (Sp. Gr. 1.12) are added, the mixture concentrated until dense fumes are given off; the precipitate is redissolved in hot water, a little more perchloric acid added, and the whole concentrated again to the fuming stage, allowed to cool, and 20 cc. 95% alcohol added with stirring. After decanting the clear alcohol, 20 cc. alcohol, containing 0.2% perchloric acid, are added, and the insoluble potassium perchlorate transferred as completely as possible by means of it to a tared filter paper, or to a weighed Gooch crucible or Soxhlet tube well packed with asbestos. The acid alcohol is allowed to drain away as completely as possible, and the whole of the precipitate collected in the paper, crucible or tube, and washed till no longer acid, with 95% alcohol saturated at the laboratory temperature with potassium perchlorate. The precipitate is dried at  $100^{\circ}\text{C}.$ , and weighed at  $\text{KClO}_4$ . Care must be taken that the perchloric acid is pure. Chloric acid is sometimes present in impure samples, and, besides leading to deflagrations on the addition of alcohol, gives rise to high results. Christensen and Feilberg (*Landw. Vers.-St.*, 1921, **97**, 27) have modified the cobaltinitrite method due to Mitscherlich, and claim that in its improved form it yields accurate results.

*Phosphoric acid.* The charred residue from which the potassium chloride has been removed is digested for  $\frac{1}{2}$  hr. with 50 cc. of 10% sulphuric acid and filtered; the filtrate is treated with 25 cc. of concentrated ammonium nitrate solution, and warmed to  $55^{\circ}\text{C}.$ ; 25 cc. ammonium molybdate, previously warmed to  $55^{\circ}\text{C}.$ , is added, and the liquid allowed to stand for 2 hrs. and filtered. After washing with 2% sodium nitrate until neutral, the precipitate and filter paper are transferred to the beaker used for the precipitation, and a known volume of standard alkali added so that the precipitate dissolves completely. The excess alkali is determined by titration, using phenolphthalein as indicator.

1 cc. of N/10 alkali = 0.0003004 grm.  $\text{P}_2\text{O}_5$ .

Originally described in *Bull.* 46 (revised) *United States Division of Chemistry* (Washington, 1898), this volumetric method has been carefully examined by Prescott (*Journ. Agric. Sci.*, 1914, **6**, 111), and the above conditions laid down under which it gives satisfactory results. The method is applicable for the "available"  $\text{P}_2\text{O}_5$ , but in this case the residue from the citric acid extraction (see later) is first heated for 2 hrs. at  $120^{\circ}$  to  $160^{\circ}\text{C}.$  to render the silica insoluble. Instead of the above volumetric method, the

yellow precipitate of ammonium phosphomolybdate, obtained as above, can be filtered on a Gooch crucible, and either weighed as  $(\text{NH}_4)_3\text{PO}_4 \cdot 12\text{MoO}_3$  (factor for  $\text{P}_2\text{O}_5 = 0.03753$ ) after drying at  $160\text{--}180^\circ\text{C}$ ., or, more conveniently, ignited gently (inside a nickel crucible lined at the bottom with asbestos paper), to the bluish-black phosphomolybdic anhydride,  $24\text{MoO}_3 \cdot \text{P}_2\text{O}_5$  (containing 3.946%  $\text{P}_2\text{O}_5$ ), and weighed in this form. The older method is described by Dyer (*Journ. Chem. Soc.*, 1894, **65**, 116).

*Available potash and phosphoric acid.* Dyer's directions are as follows: 200 grm. dry soil are placed in a  $2\frac{1}{2}$  litre bottle with 2 litres of distilled water in which are 20 grm. of pure citric acid. The soil is allowed to remain in contact with the solution at ordinary temperatures for 7 days, shaking several times each day. Substantially similar results are obtained by shaking for 24 hrs. in a mechanical shaker (Hall and Amos, *Journ. Chem. Soc.*, 1906, **89**, 205). The solution is then filtered, and 500 cc. taken for each determination; this is evaporated to dryness, and gently incinerated at a low temperature. The residue is moistened with concentrated hydrochloric acid, the liquid evaporated to dryness, the residue gently ignited, and then extracted with hot water and filtered; the potash is determined in the filtrate. For the phosphoric acid determination the final solution of the residue is carried out, as before, with 10% sulphuric acid.

*Mechanical analysis.* The object is to obtain information about the size of the ultimate particles of which the soil is composed; the compound particles are therefore broken down by treatment with hydrochloric acid, and afterwards with ammonia. Direct measurement of the ultimate particles is found to be impracticable; indirect methods have to be adopted, depending on the time taken to fall through a column of water of given height. If  $v$  = velocity of the falling particle,  $a$  its radius (assuming it to be a sphere), it has been calculated that  $a = \sqrt{v/171}$  cm.

The method adopted by the Agricultural Education Association (*Journ. Agric. Sci.*, 1906, **1**, 470) is as follows:

(1) 10 grm. of the air-dried earth, which has passed a 3 mm. sieve, are weighed into a porcelain basin and triturated with 100 cc. of N/5 hydrochloric acid, further acid being added if much calcium carbonate is present. After standing in contact with the acid for 1 hr., the mixture is transferred to a dried, tared filter, which is washed until acid-free, dried and weighed. The loss represents hygroscopic moisture and material dissolved by the acid.



(2) The soil is washed off the filter with ammoniacal water on to a small sieve of 100 meshes to the linear inch, the portion passing through being collected in a beaker marked at 10, 8.5, and 7.5 cm. respectively from the bottom. The portion which remains upon the sieve is dried, weighed, and divided into "fine gravel" and "coarse sand" by means of a sieve with round holes of 1 mm. diam. The portion which does not pass this sieve is the "fine gravel." This should be dried and weighed. The difference gives the "coarse sand." If required, both these fractions may also be weighed after ignition.

(3) The portion which passed the 100 mesh sieve is triturated with a rubber pestle (made by inserting a glass rod as handle into an inverted rubber stopper), and the beaker filled up to the 8.5 cm. mark and allowed to stand for 24 hrs. The ammoniacal liquid which contains the "clay" is then decanted into a Winchester quart, repeating the operation as long as any matter remains in suspension for 24 hrs. The liquid containing the "clay" is either evaporated in bulk or measured, and, after being well shaken, an aliquot portion taken and evaporated. In either case the dried residue consists of "clay" and "soluble humus." After ignition the residue gives the "clay," and the loss on ignition the "soluble humus."

The minimum value of  $v = 0.00001$  cm. per sec., and the minimum diameter of the particles = 0.0013 mm.

(4) The sediment from which the "clay" has been removed is triturated, as before, in the beaker, which is filled to the 10 cm. mark and allowed to stand for 100 secs. The operation is repeated until the "fine sand" settled in 100 secs. is clean, when it is collected, dried and weighed.

The minimum value of  $v = 0.1$  cm. per sec., and the calculated minimum diameter = 0.037 mm.

(5) The turbid liquid decanted from the "fine sand" is collected in a Winchester quart, or other suitable vessel, allowed to settle, and the clear liquid syphoned or decanted off. The sediment is then washed into the marked beaker and made up to the 7.5 cm. mark. After stirring, it is allowed to settle for  $12\frac{1}{2}$  mins., and the liquid decanted off. The operation is then repeated as before until all the sediment sinks in  $12\frac{1}{2}$  mins., leaving the liquid quite clear. The sediment obtained is the "silt," which is dried and weighed as usual. The liquid contains the "fine silt," which, when it has settled down, can be separated by decanting off the clear liquid, and dried and weighed.

For silt the minimum value of  $v = 0.01$  cm. per sec. and the

minimum diameter of particles = 0.012 mm. For fine silt the diameter lies between this value, and the one found for clay.

When it is desired to compare the results with American data the fine silt can be divided into two groups: settling for 2 hrs. 5 mins. brings out a group 0.01 to 0.005 mm. diam., and the remainder lies between 0.005 and 0.002 mm. diam. By calculation the fractions can then be made to correspond fairly closely with those adopted in the United States.

(6) Determinations are made of the "moisture" and "loss on ignition" of a further 10 grm. of the air-dried earth. The sum of the weights of the fractions after ignition + loss on ignition + moisture + material dissolved in weak acid should approximate to 10 grm.

(7) It is advisable to make a control determination of the "fine gravel" in a portion of 50 grm. of the air-dried earth. The soil should be treated with acid, as in (1), and after that is removed by decantation may be at once treated with dilute ammonia and washed on the sieve with 1 mm. round holes. The "fine gravel" left on the sieve is then dried and weighed.

Joseph and Martin (*Journ. Agric. Sci.*, 1922, **11**, 293) describe a sedimentation method similar to the British one, but using sodium carbonate instead of ammonia for deflocculating the clay, and using the centrifuge to hasten the rate of settling. Good results were obtained with heavy Sudan soils.

An entirely new method has been described by Oden (*Internat. Mitt. Bodenkunde.*, 1915, **5**, 251-346). Expensive and complicated apparatus is, however, needed for this method, which is thus only suitable for research purposes. A simple and promising method has recently been devised by Robinson (*Journ. Agric. Sci.*, 1922, **12**, 306).

### *Interpretation of Results.*

This is by no means an easy problem; it is discussed at length by Hall (*The Soil*), and by Russell (*Soil Conditions and Plant Growth*).

Some typical results are given in the table on the page following.

### *Bacteriological Examination of Soils.*

The method of counting the number of bacteria present in soils, which has been worked out at Rothamsted, is as follows:—

The freshly sampled soil is passed through a 3 mm. sieve



and thoroughly mixed (aseptic technique is not needed at this point, unless qualitative examination for species is also contemplated). 10 gm. are weighed out, transferred to 250 cc. of sterile saline (5 gm. NaCl, 1 gm.  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ , 1 litre  $\text{H}_2\text{O}$ ), and the flask shaken for 4 mins., the cotton wool plug being replaced by a sterile cork. 1 cc. of the resulting suspension is transferred by means of a sterile pipette into 99 cc. of sterile saline and shaken for 1 min. 1 cc. of this suspension is similarly transferred to a second 99 cc. of sterile saline and shaken for 1 min. (In making these transfers it is best to wash out the pipette once with the liquid to which the suspension has just been added, so as to minimise loss of organisms due to adherence to the pipette walls.) Five sterile petri dishes are taken, and to each is transferred with a sterile pipette 1 cc. of the final suspension (equals  $1/250\,000$  gm. of soil). Before each transfer the flask should be shaken to ensure an even suspension. Into each dish is then poured about 10 cc. of sterile count medium (see below) previously melted and cooled to  $42^\circ\text{C}$ ., and the dish at once carefully oscillated so as to mix the medium well with the soil suspension and give a uniform mixture before the medium sets. The plates are allowed to stand till the medium is quite firm, then they are incubated in an inverted position at  $20^\circ\text{C}$ . for 10 days. The number of colonies on each plate is counted (some practice is needed to distinguish bacterial colonies from those of moulds and acetomycetes) and the mean value for the five plates, divided by four, gives the number of bacteria in the fresh soil in millions per gramme (m.p.g.). The result is a minimum one, since the whole of the bacteria in the soil are incapable of developing on any one medium, but the value obtained should be quite suitable for comparative purposes.

*Agar count medium* (Thornton, *Ann. Appl. Biol.*, 1922, **9**, 241).  $\text{K}_2\text{HPO}_4$  1 gm.,  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  0.2 gm.,  $\text{CaCl}_2$  0.1 gm., NaCl 0.1 gm.,  $\text{KNO}_3$  0.5 gm.,  $\text{FeCl}_3$  0.002 gm., asparagine 0.5 gm., mannitol 1 gm., agar 15 gm., water to 1000 cc. The phosphate, nitrate and asparagine are first added, followed by the other salts, previously dissolved in water, and finally the agar. The whole is heated in the steamer until the agar is dissolved, and then filtered in the steamer at  $100^\circ\text{C}$ ., being passed twice through a  $\frac{1}{2}$  in. layer of absorbent cotton wool. The mannitol is added to the filtrate, and the reaction of the medium adjusted to pH 7.4 with caustic soda (see Gillespie, *Soil Sci.*, 1920 **9**, 115, for simple method of adjusting pH). It is filled into tubes in 10 cc. lots and sterilized in the autoclave at 15 lb. for 15 mins.

# Mechanical and Chemical Analysis of Typical Soils.

| Formation                                   |       | Folkestone Beds. |       | Thanet Beds.    |       | Brick             |       | Earth             |       | London Weald Clay  |       | Alluvium          |       |
|---|-------|------------------|-------|-----------------|-------|-------------------|-------|-------------------|-------|--------------------|-------|-------------------|-------|
| Character of Soil.                          |       | Waste.           |       | Good but light. |       | Very good arable. |       | Very good arable. |       | Heavy, grass best. |       | Heavy poor grass. |       |
|   |       |                  |       |                 |       |                   |       |                   |       |                    |       |                   |       |
| Gravel                                      | ..... | 1.2              | 2.5   | 0.2             | 0.2   | 0.2               | 0.3   | 0.9               | 0.4   | 0.4                | 0.7   | 0.7               | 0.1   |
| Coarse Sand                                 | ..... | 65.9             | 52.6  | 15.3            | 15.3  | 2.3               | 0.7   | 1.3               | 12.8  | 1.5                | 1.0   | 1.0               | 0.5   |
| Fine Sand                                   | ..... | 23.7             | 25.2  | 44.9            | 44.9  | 34.7              | 24.7  | 16.0              | 25.5  | 11.0               | 19.8  | 19.8              | 19.3  |
| Silt  | ..... | 2.4              | 4.8   | 17.3            | 17.3  | 36.2              | 44.8  | 35.5              | 11.3  | 19.6               | 28.4  | 28.4              | 13.0  |
| Fine Silt                                   | ..... | 2.0              | 3.5   | 6.3             | 6.3   | 6.3               | 8.6   | 13.3              | 11.1  | 26.8               | 12.1  | 12.1              | 20.0  |
| Clay  | ..... | 0.9              | 3.8   | 8.9             | 8.9   | 11.5              | 14.7  | 15.9              | 23.7  | 22.1               | 19.7  | 19.7              | 26.9  |
| <hr/>                                       |       |                  |       |                 |       |                   |       |                   |       |                    |       |                   |       |
| Moisture                                    | ..... | 0.48             | 1.11  | 2.21            | 2.21  | 2.27              | 2.45  | 3.32              | 4.92  | 4.87               | 4.76  | 4.76              | 4.00  |
| Loss on ignition                            | ..... | 2.62             | 3.27  | 3.17            | 3.17  | 4.32              | 4.65  | 6.58              | 5.61  | 9.80               | 10.21 | 10.21             | 11.33 |
| Nitrogen                                    | ..... | 0.033            | 0.137 | 0.119           | 0.119 | 0.140             | 0.120 | 0.220             | 0.241 | 0.310              | 0.339 | 0.339             | 0.354 |
| Al <sub>2</sub> O <sub>3</sub>              | ..... | nil              | 1.55  | 2.07            | 2.07  | 3.46              | 3.33  | 5.50              | 5.95  | —                  | 6.45  | 6.45              | —     |
| Fe <sub>2</sub> O <sub>3</sub>              | ..... | 2.24             | 5.24  | 2.44            | 2.44  | 2.56              | 2.50  | 3.05              | 3.80  | —                  | 4.26  | 4.26              | —     |
| Mn <sub>2</sub> O <sub>4</sub>              | ..... | trace            | 0.03  | trace           | trace | 0.02              | 0.05  | 0.06              | 0.03  | —                  | nil   | nil               | —     |
| MgO   | ..... | 0.06             | 0.18  | 0.32            | 0.32  | 0.46              | 0.52  | 0.40              | 0.97  | —                  | 0.30  | 0.30              | —     |
| *Carbonates                                 | ..... | nil              | 0.35  | 0.08            | 0.08  | 0.18              | 0.40  | 0.75              | 2.00  | 0.16               | 0.05  | 0.05              | 0.28  |
| CaO   | ..... | 0.05             | 0.41  | 0.51            | 0.51  | 0.67              | 0.82  | 1.79              | 1.51  | —                  | 0.81  | 0.81              | —     |
| K <sub>2</sub> O                            | ..... | 0.025            | 0.158 | 0.392           | 0.392 | 0.404             | 0.31  | 0.43              | 0.54  | 0.46               | 0.51  | 0.51              | 0.22  |
| + "Available" K <sub>2</sub> O              | ..... | 0.010            | 0.007 | 0.012           | 0.012 | 0.015             | 0.010 | 0.014             | 0.016 | 0.006              | 0.031 | 0.031             | 0.014 |
| P <sub>2</sub> O <sub>5</sub>               | ..... | 0.081            | 0.191 | 0.064           | 0.064 | 0.119             | 0.074 | 0.138             | 0.118 | 0.104              | 0.343 | 0.343             | 0.102 |
| + "Available" P <sub>2</sub> O <sub>5</sub> | ..... | 0.004            | 0.047 | 0.013           | 0.013 | 0.048             | 0.008 | 0.020             | 0.019 | 0.003              | 0.064 | 0.064             | 0.006 |
| SO <sub>3</sub>                             | ..... | —                | 0.034 | 0.04            | 0.04  | 0.05              | 0.03  | 0.06              | 0.05  | —                  | 0.08  | 0.08              | —     |
| <hr/>                                       |       |                  |       |                 |       |                   |       |                   |       |                    |       |                   |       |
| Moisture                                    | ..... | 0.48             | 1.06  | —               | —     | 2.67              | 3.15  | 3.21              | 6.88  | 3.46               | 4.55  | 4.55              | 3.84  |
| Loss on ignition                            | ..... | 2.03             | 2.25  | —               | —     | 3.09              | 3.00  | 4.94              | 5.07  | 2.59               | 7.33  | 7.33              | 8.84  |
| Nitrogen                                    | ..... | 0.026            | 0.059 | —               | —     | 0.088             | 0.078 | 0.139             | 0.097 | 0.129              | 0.173 | 0.173             | 0.202 |
| *Carbonates                                 | ..... | 0.02             | 0.12  | —               | —     | 0.03              | 0.08  | 0.66              | 0.52  | 54.8               | nil   | nil               | 0.19  |
| K <sub>2</sub> O                            | ..... | 0.014            | 0.144 | —               | —     | 0.441             | 0.46  | 0.47              | 0.572 | 0.229              | 0.75  | 0.75              | 0.34  |
| P <sub>2</sub> O <sub>5</sub>               | ..... | 0.044            | 0.174 | —               | —     | 0.053             | 0.067 | 0.101             | 0.042 | 0.036              | 0.245 | 0.245             | 0.079 |

\*Calculated as CaCO<sub>3</sub>.

†Soluble in 1% Citric Acid

SOIL.

SUBSOIL.

## Analysis of Manures.

Unlike the analysis of soils, the analysis of manures is not a comparative process, but aims at obtaining absolute results. In the case of phosphatic fertilisers it is necessary to give some indication as to solubility, and in that case carefully prescribed methods must be followed. Official methods (*Board of Agriculture Leaflet*, No. 18) have been prescribed for sampling and for all determinations, and these must be rigidly followed wherever a dispute is likely to be involved.

The sample must be prepared for analysis in the following manner: Powdered fertilisers in a dry, or moderately dry, condition must first be passed through a 1 mm. mesh sieve, powdering if necessary; adventitious materials which cannot be conveniently crushed, *e.g.*, fragments of metal in basic slag, are removed and allowed for. Wool, hair, hoof, shoddy, and similar substances, are pulled apart and cut until in a fine condition, or, if dry, may be passed through a shredding machine. In the case of horn, shoddy, and other substances which gain or lose water during the process of pulverising, the proportion of water is estimated in the coarse and in the powdered condition respectively, and the results of the analysis of the powdered sample are calculated to the original substance.

The official method of analysis is as follows:

*Determination of moisture.* A weighed quantity of the sample is dried at  $100^{\circ}\text{C}$ .

*Determination of nitrogen.* The presence or absence of nitrates must first be ascertained.

(a) In absence of nitrates a weighed portion of the sample is transferred to a Kjeldahl flask, 10 grm. of potassium sulphate and 25 cc. of concentrated sulphuric acid added, and the flask heated until a clear liquid, colourless, or of light straw colour, is obtained. The operation may be accelerated by the addition of a small crystal of copper sulphate or a globule of mercury to the liquid in the digestion flask. The quantity of ammonia determined by distillation into standard acid after liberation with alkali, and, where mercury has been used, with the addition also of sodium or potassium sulphide solution.

(b) In presence of nitrates, a weighed portion of the sample is transferred to a Kjeldahl flask, 30 cc. of concentrated sulphuric acid containing 1 grm of salicylic acid added, and the flask shaken immediately and at intervals during 10 mins., being kept cool meanwhile. 5 grm. of sodium thiosulphate and 10 grm. of potassium sulphate are added, and the flask heated until the contents are colorless or nearly so. Copper sulphate

or mercury may be used as described above. The quantity of ammonia is determined as above.

(c) Nitrogen in form of ammonium salts is determined after addition of alkali in the usual manner.

(d) Nitrogen in nitrates in the absence of ammonium salts and of organic nitrogen: 1 grm. of the sample is placed in  $\frac{1}{2}$  litre Erlenmeyer flask with 50 cc. of water, 10 grm. of reduced iron and 20 cc. of sulphuric acid (Sp. Gr. 1.35) added and the flask closed with a rubber stopper provided with a thistle tube, the head of which is half-filled with glass beads. The liquid is boiled for 5 mins., and the beads rinsed with water into the flask. The solution should be boiled for 3 mins. more. After boiling for a further 3 mins. the beads are again washed with water. The quantity of ammonia is then determined as above. In case the proportion of nitrates is small, a larger quantity of the sample is taken.

(e) A control experiment is carried out under similar conditions with the same quantities of the reagents which have been employed in the actual analysis, 1 grm. of pure sugar being used in (a) in place of the sample; a suitable correction is then made.

### *Determination of phosphates.*

(a) Phosphates soluble in water. In the case of superphosphates, dissolved bones and similar substances, 20 grm. of the sample are shaken continuously for 30 mins. in a litre flask with 800 cc. of water. The flask is then filled to the mark again shaken, and the contents filtered. 50 cc. of the filtrate are boiled with 20 cc. of concentrated nitric acid, and the phosphoric acid determined by the molybdate method described below. In the case of fertilisers in which the proportion of phosphates soluble in water is small, a larger quantity of the filtrate prepared as above is taken.

(b) Phosphates soluble in citric acid. 5 grm. of the sample are treated with 10 grm. of pure crystallised citric acid, made up to 500 cc. with water. To avoid caking, the sample may be moistened with 5 cc. of methylated spirit before the citric acid solution is added, in which case the volume of the citric acid solution should be 495 cc. instead of 500 cc. The bottle is at once fitted into a mechanical shaking apparatus and continuously agitated for 30 mins. The solution is then filtered through a large fluted filter, the whole of the liquid being poured on the paper at once; if not clear, the filtrate is again poured through the same paper. The phosphoric acid is determined in 50 cc. of the filtrate by the molybdate method described below.

(c) Total phosphoric acid. A weighed portion of the sample, in which, if necessary, the organic matter has been destroyed by ignition and the silica removed, is dissolved in nitric acid, the solution boiled, and the phosphoric acid determined by the molybdate method.

(d) Molybdate method. Molybdic acid solution: 125 grm. of molybdic acid and 100 cc. of water are placed in a litre flask, and the molybdic acid dissolved by shaking with 300 cc. of 8% ammonia (Sp. Gr. 0.967); 400 grm. of ammonium nitrate are added, the solution made up to the mark with water, and added to 1 litre of nitric acid (Sp. Gr. 1.19). After keeping at about 35°C. for 24 hrs., the solution is filtered.

Magnesia mixture: 110 grm. of crystallised magnesium chloride and 140 grm. of ammonium chloride, dissolved in 1,300 cc. of water, are mixed with 700 cc. of 8% ammonia, allowed to stand for not less than 3 days, and then filtered.

An amount of the solution, containing from 0.1–0.2 grm. of  $P_2O_5$ , is treated with 100 to 150 cc. or an excess of molybdic acid solution, and the mixture placed in a water-bath at 70°C., for 15 mins. After allowing to cool, the solution is filtered, and the phospho-molybdate precipitate washed several times by decantation and finally on to the filter with 1% nitric acid. The filtrate and washings are mixed with further molybdic acid solution and allowed to stand for some time in a warm place in order to ascertain whether the  $P_2O_5$  has been completely precipitated. The phospho-molybdate precipitate is dissolved in cold 2% ammonia, using about 100 cc. of ammonia for the solution and washings. 15–20 cc. or an excess of magnesia mixture is then added drop by drop with constant stirring. After allowing to stand for at least 2 hrs. with occasional stirring, the precipitate is filtered off, washed with 2% ammonia, dried and finally weighed as magnesium pyrophosphate. The filtrate and washings are tested by the addition of further magnesia mixture.

### *Determination of potash.*

(a) Muriate of potash free from sulphates. A weighed portion of the sample (about 5 grm. in the case of concentrated muriate of potash or 10 grm. in the case of low-grade muriate) is dissolved in water, the solution filtered if necessary, and made up to 500 cc. To 50 cc. of the solution in a porcelain basin, several drops of HCl are added, and then 10 cc. or 20 cc. (according to whether the portion weighed was 5 grm. or 10 grm.) of a solution of platinum chloride containing 10 grm. Pt per 100 cc. After evaporation to a syrupy consistency on a water-bath, the contents of the basin are allowed to cool,



and then treated with alcohol (Sp. Gr. 0.864), being washed by decantation until the alcohol is colorless. The washings are filtered through a weighed or counterpoised filter paper, on which the precipitate is finally collected, washed with alcohol as above, dried at  $100^{\circ}\text{C}.$ , and weighed as  $\text{K}_2\text{PtCl}_6$ .

(b) Potassium salts containing sulphates. A weighed portion of the sample (about 5 grm. in the case of concentrated sulphate of potash or 10 grm. in the case of kainit or other low-grade salts) are boiled with 20 cc. of hydrochloric acid and 300 cc. of water in a  $\frac{1}{2}$  litre flask. Barium chloride solution is added drop by drop to the boiling solution until the sulphuric acid is completely precipitated; any slight excess of barium is removed by the addition of the least possible excess of dilute sulphuric acid. (It is often more convenient to estimate the sulphuric acid and add the exact amount of barium chloride.) The liquid, without filtration, is cooled and made up to 500 cc. A portion is then filtered, and 50 cc. of the filtrate treated as in (a).

(c) Potash in guanos and mixed fertilisers. 10 grm. of the sample are gently ignited to char organic matter present, heated for 10 mins. with 10 cc. of concentrated hydrochloric acid, and finally boiled with 300 cc. of water. The liquid is filtered into a  $\frac{1}{2}$  litre flask, raised to the boiling point, and a slight excess of powdered barium hydroxide added. The contents of the flask are cooled, made up to 500 cc., and filtered. 250 cc. of the filtrate are treated with ammonia solution and excess of ammonium carbonate, and then, whilst boiling, with a small amount of powdered ammonium oxalate, cooled, made up to 500 cc. and filtered. 100 cc. of the filtrate are evaporated in a platinum dish, and the residue heated, first in the air-bath and then very gently over a low flame, until all ammonium salts are expelled, the temperature being carefully kept below that of low redness. The residue is treated with hot water, filtered if necessary, and the potash determined in the filtrate as in (a).

In case no prosecution is likely to be involved, the analyst may use the perchlorate method for determining potash given under "Soil analysis," using, however, sufficient perchloric acid to precipitate the larger amounts of potash in the solution obtained as above.

An account of the preparation and properties of the various fertilisers is given by Hall (*Fertilisers and Manures*), and by Russell (*Soils and Manures*).

The adjoining table gives the composition of typical fertilisers.

## TYPICAL ANALYSES OF FERTILISERS.

| Fertiliser.          | Nitrogen. | Equivt. $\text{NH}_3$ . | $\text{P}_2\text{O}_5$ . | Equivt. to $\text{Ca}_3(\text{PO}_4)_2$ . | $\text{K}_2\text{O}$ . | Moisture. | Organic Matter. | Sand. |
|----------------------|-----------|-------------------------|--------------------------|---|------------------------|-----------|-----------------|-------|
| Nitrate of Soda ..   | 15.5      |                         |                          |   |                        |           |                 |       |
| Nitrate of Potash .. | 14.0      |                         |                          |   |                        |           |                 |       |
| Nitrate of Lime ..   | 13.0      |                         |                          |   |                        |           |                 |       |
| Sulphate of Amm.     | 20.0      |                         |                          |   |                        |           |                 |       |
| Nitrolim ..          | 15.5      | 18.8                    |                          |   |                        |           |                 |       |
| Bones (Raw) .....    | 5.0       | 6                       | 22                       | 48  |                        |           |                 |       |
| Bone Meal .....      | 3.5-5.0   | 5-6                     | 20-25                    | 43-55                                     |                        |           |                 |       |
| Steamed Bone Flour   | 1-2       | 1-2.5                   | 25-32                    | 55-69                                     |                        |           |                 |       |
| Dissolved Bones ..   | 2-3       | 2.3-3.8                 | 15-16                    | 33-35                                     |                        |           |                 |       |
| Superphosphate ..    |           |                         | 11.8                     | 26  |                        |           |                 |       |
| "                    |           |                         | 13.6                     | 30  |                        |           |                 |       |
| "                    |           |                         | 16.0                     | 35  |                        |           |                 |       |
| Basic Slag—          |           |                         |                          |   |                        |           |                 |       |
| Bessemer .....       |           |                         | 20                       | 44 <sup>1</sup>                           |                        |           |                 |       |
| Open Hearth ..       |           |                         | 9-15                     | 20-33 <sup>2</sup>                        |                        |           |                 |       |
| Sulphate of Potash   |           |                         |                          |   | 48.5                   |           |                 |       |
| Muriate of Potash    |           |                         |                          |   | 45                     |           |                 |       |
| Kainit .....         |           |                         |                          |   | 12                     |           |                 |       |
| Wood Ashes .....     |           |                         |                          |   | 10                     |           |                 |       |
| Farmyard Manure—     |           |                         |                          |   |                        |           |                 |       |
| Bullock .....        | 0.62      |                         | 0.26                     |   | 0.72                   |           |                 |       |
| Cow .....            | 0.43      |                         | 0.19                     |   | 0.44                   |           |                 |       |
| Horse .....          | 0.54      |                         | 0.23                     |   | 0.54                   |           |                 |       |
| Liquid .....         | 0.20      |                         | 0.03                     |   | 0.46                   |           |                 |       |

<sup>1</sup> 80-90 % soluble in 2% citric acid.<sup>2</sup> 20-80% soluble in 2% citric acid.



TYPICAL ANALYSES OF FERTILISERS. —Continued.

| Fertiliser.           | Nitrogen. | Equivt. $\text{NH}_3$ . | $\text{P}_2\text{O}_5$ . | Equivt. $\text{Ca}_3(\text{PO}_4)_2$ . | $\text{K}_2\text{O}$ . | Moisture. | Organic Matter. | Sand. |
|-----------------------|-----------|-------------------------|--------------------------|--|------------------------|-----------|-----------------|-------|
| Peruvian Guano—       |           |                         |                          |  |                        |           |                 |       |
| High Grade ..         | 10–14     |                         | 9–11                     | 20–24                                  | 2–4                    |           | 60–70           | 7–12  |
| Ordinary „ ..         | 5–8       |                         | 14–18                    | 30–40                                  | 2–4                    |           | 40–50           | 9–25  |
| Phosphatic ...        | 2.5–3.5   |                         | 18–32                    | 40–70                                  | 2–6                    |           | 22–25           | 4–6   |
| Ichaboe Guano ..      | 8         |                         | 9–14                     | 20–30                                  | 2                      |           | 50–60           | 15–25 |
| Fish Guano .....      | 8–10      |                         | 4.5–9                    | 10–20                                  |                        |           |                 |       |
| Pure Flesh (fat-free) | 16.7      |                         |                          |  |                        |           |                 |       |
| Meat Guano—           |           |                         |                          |  |                        |           |                 |       |
| High Grade ..         | 8–9       |                         | 4.6–7                    | 10–14                                  |                        |           |                 |       |
| Phosphatic ..         | 4–5       |                         | 16–18                    | 35–40                                  |                        |           |                 |       |
| Blood (dried) ....    | 12        |                         |                          |  |                        |           |                 |       |
| Hoofs and Horns ..    | 12–14     |                         |                          |  |                        |           |                 |       |
| „ mixed with Bone     | 10        |                         |                          | 20–25                                  |                        |           |                 |       |
| Rape Cake .....       | 5         |                         | 2                        | 4                                      |                        |           |                 |       |
| Seaweed (wet) ....    | 0.5       |                         | 0.09                     |  |                        | 75        | 18              |       |
| Shoddy—               |           |                         |                          |  |                        |           |                 |       |
| High Grade ..         | 12–14     |                         |                          |  |                        |           |                 |       |
| Medium „ ..           | 5–8       |                         |                          |  |                        |           |                 |       |
| Low „ ..              | 3         |                         |                          |  |                        |           |                 |       |
| Hair, Calf hair, &c.  | 10        |                         |                          |  |                        |           |                 |       |
| Feathers .....        | 9         |                         |                          |  |                        |           |                 |       |
| Rabbit Waste          |           |                         |                          |  |                        |           |                 |       |
| Leather Waste         | 7         |                         |                          |  |                        |           |                 |       |
| Soot .....            | 3.3       | 4                       |                          |  |                        |           |                 |       |
| Sewage Sludge ....    | 1         |                         |                          |  |                        | 50        | 15–25           | 25–35 |
| + lime                |           |                         |                          |  |                        |           |                 |       |

## Analysis of Feeding Stuffs.

This is distinctly more conventional than the analysis of fertilisers or even of soils, and is therefore more definitely limited in its scope, the main object of the analysis being to compare one feeding stuff with another of the same kind. Analysis rarely affords a sufficient basis on which to pronounce an opinion on an unknown material, as it can never show whether the material will prove palatable or even poisonous to the animal. Feeding trials must always be made with new substances.

The method of sampling and of analysis of feeding stuffs are prescribed in the *Board of Agriculture Leaflet*, No. 18.

The sample is prepared for analysis in the following manner: If the sample is not in a fine condition, it is carefully pulverised until it passes through a 2-3 mm. sieve, thoroughly mixed, and a portion immediately taken for the determination of moisture by drying at 100°C. A portion of not less than 100 grm. is further powdered if necessary to pass through a 1 mm. sieve and preserved in a stoppered bottle.

In case the original sample is appreciably damp, or if pulverisation and mixing are likely to result in loss or gain of moisture, the moisture is redetermined in this portion, and the results of analysis suitably corrected.

### *Determination of oil.*

A quantity of the sample is weighed into a thimble, and extracted with washed redistilled ether in a Soxhlet apparatus. After 3-4 hrs. the thimble is removed, dried, and its contents finely ground in a small mortar previously rinsed with ether; the substance is then returned to the thimble, the mortar being washed out with ether, and the extraction continued for another hour. After evaporation of the ether the oil is dried at 100°C. and weighed. The oil is then redissolved in ether and any insoluble matter weighed and deducted.

In the case of samples containing saccharine matter, *e.g.*, sugar meals, the weighed portion in the Soxhlet thimble is washed twice with water and then dried, previous to the extraction.

### *Determination of fibre.*

The residue in the thimble is transferred to a beaker, 50 cc. of 5%  $\text{H}_2\text{SO}_4$  and 75 cc. water are added, and the liquid boiled gently for  $\frac{1}{2}$  hr., stirring to avoid frothing, hot water being added as required to keep the volume constant. Cold water is added, and the mixture allowed to stand for 1 hr. The liquid is then filtered through linen, and the

residue washed back into the beaker with a small amount of hot water. 50 cc. of 5% KOH are added, and the liquid made up with water to the original volume, boiled for  $\frac{1}{2}$  hr.; cold water is then added, and the liquid allowed to stand and again filtered through linen, washing with hot water, then dilute hydrochloric acid, and finally with alcohol. The residue is transferred to a crucible, dried, and weighed; it is then ignited to obtain weight of mineral matter, which must be deducted from the weight of fibre.

*Carbohydrates* are estimated by difference; the content of oil, fibre, albuminoids, moisture and total ash is subtracted from 100 per cent.

#### *Determination of albuminoids.*

The total nitrogen is determined by the Kjeldahl method as under "Manures."

$$\% \text{ albuminoids} = 6.25 \times \% \text{ N.}$$

The properties of feeding stuffs are described by Henry (*Feeds and Feeding*), Kellner (translated by Goodwin, *Scientific Feeding of Farm Animals*), and Armsby (*Principles of Animal Nutrition*).

A complete list of the composition of typical feeding stuffs has been published by Wood (*Composition and Nutritive Value of Feeding Stuffs*).

### Average Percentage Composition of Typical Feeding Stuffs.

(Wood, "Composition and Nutritive Value of Feeding Stuffs.")

|   |  | Water. | Protein. | Oil. | Carbohy-<br>drate. | Fibre. | Ash. |
|---|--|--------|----------|------|--------------------|--------|------|
| <i>Roots.</i>                                       |  |        |          |      |                    |        |      |
| Mangolds (yellow fleshed,<br>globe or tankard) .... |  | 86.8   | 1.2      | 0.1  | 9.9                | 0.8    | 0.9  |
| Potatoes .....                                      |  | 76.2   | 2.1      | 0.1  | 19.7               | 0.9    | 1.0  |
| Sugar Beet .....                                    |  | 76.6   | 1.1      | 0.1  | 20.4               | 1.1    | 0.7  |
| Turnip .....  |  | 91.5   | 1.0      | 0.2  | 5.7                | 0.9    | 0.7  |
| <i>Grasses.</i>                                     |  |        |          |      |                    |        |      |
| Pasture Grass, average.....                         |  | 80.0   | 3.5      | 0.8  | 9.7                | 4.0    | 2.0  |
| " rich .....  |  | 78.2   | 4.5      | 1.0  | 10.1               | 4.0    | 2.2  |
| <i>Hay.</i>   |  |        |          |      |                    |        |      |
| Meadow Hay, poor .....                              |  | 14.3   | 7.5      | 1.5  | 38.2               | 33.5   | 5.0  |
| " good .....  |  | 14.3   | 9.7      | 2.5  | 41.4               | 26.3   | 6.2  |
| " very good ....                                    |  | 16.0   | 13.5     | 3.0  | 40.4               | 19.3   | 7.7  |
| <i>Straws.</i>                                      |  |        |          |      |                    |        |      |
| Barley Straw, Spring .....                          |  | 14.0   | 3.3      | 1.8  | 42.4               | 33.9   | 4.6  |
| Bean Straw (incl. pods) .....                       |  | 14.0   | 4.5      | 0.8  | 33.0               | 43.5   | 4.6  |
| Oat Straw, Spring .....                             |  | 14.0   | 2.9      | 1.9  | 42.4               | 33.9   | 4.9  |
| " Winter .....                                      |  | 14.0   | 1.9      | 1.5  | 43.1               | 34.6   | 4.9  |
| Wheat Straw, Spring .....                           |  | 14.0   | 2.9      | 1.3  | 39.8               | 35.9   | 6.1  |
| " Winter .....                                      |  | 14.0   | 2.1      | 1.3  | 40.7               | 36.6   | 5.3  |

|   | Water. | Protein. | Oil. | Carbohy-<br>drate. | Fibre. | Ash. |
|---|--------|----------|------|--------------------|--------|------|
| <b>Cereals.</b>                         |        |          |      |                    |        |      |
| Barley, Feeding .....                   | 14.3   | 12.0     | 2.4  | 63.7               | 5.0    | 2.0  |
| Maize .....                             | 13.0   | 9.9      | 4.4  | 69.2               | 2.2    | 1.3  |
| Oats .....                              | 13.3   | 10.3     | 4.8  | 58.2               | 10.3   | 3.1  |
| Wheat .....                             | 13.4   | 12.1     | 1.9  | 69.0               | 1.9    | 1.7  |
| <b>Legumes.</b>                         |        |          |      |                    |        |      |
| Beans .....                             | 14.3   | 25.4     | 1.5  | 48.5               | 7.1    | 3.2  |
| Peas .....                              | 14.0   | 22.5     | 1.6  | 53.7               | 5.4    | 2.8  |
| <b>Oil Seeds.</b>                       |        |          |      |                    |        |      |
| Cotton Seed, Egyptian .....             | 8.8    | 19.6     | 23.9 | 21.5               | 21.2   | 5.0  |
| "    Bombay .....                       | 8.5    | 17.9     | 19.4 | 29.9               | 20.0   | 4.3  |
| "    Brazilian .....                    | 9.4    | 21.1     | 23.2 | 25.0               | 17.0   | 4.3  |
| Ground Nuts, earth or pea ..            | 7.0    | 29.7     | 49.2 | 12.2               | 6.0    | 2.8  |
| Linseed .....                           | 7.1    | 24.2     | 36.5 | 22.9               | 5.5    | 3.8  |
| Palm Nut Kernels .....                  | 8.4    | 8.4      | 48.8 | 26.8               | 5.8    | 1.8  |
| Soya Beans .....                        | 10.0   | 33.2     | 17.5 | 30.2               | 4.1    | 4.7  |
| Sunflower Seed .....                    | 7.5    | 14.2     | 32.3 | 14.5               | 28.1   | 3.4  |
| <b>Oil Cakes and Meals.</b>             |        |          |      |                    |        |      |
| Cocoanut Cake .....                     | 9.2    | 23.7     | 8.2  | 42.0               | 11.0   | 5.9  |
| Cotton Cake, Bombay .....               | 10.0   | 22.0     | 6.1  | 35.0               | 20.9   | 6.1  |
| "    Brazilian .....                    | 11.0   | 27.1     | 5.4  | 27.1               | 24.9   | 4.5  |
| "    Egyptian .....                     | 12.1   | 23.0     | 5.5  | 32.4               | 21.2   | 5.8  |
| "    Decorticated .....                 | 9.8    | 40.2     | 9.9  | 25.9               | 7.6    | 6.6  |
| Cotton Seed Meal .....                  | 8.7    | 42.1     | 10.9 | 24.9               | 7.4    | 6.0  |
| Ground Nut Cake, Decorti-<br>cated....  | 9.4    | 47.5     | 7.1  | 25.6               | 4.6    | 5.8  |
| "    Undecorticated..                   | 10.3   | 30.2     | 9.1  | 21.8               | 22.9   | 5.7  |
| Linseed Cake, English made..            | 11.2   | 29.5     | 9.5  | 35.5               | 9.1    | 5.2  |
| "    Foreign .....                      | 11.0   | 32.3     | 9.9  | 32.2               | 8.7    | 5.9  |
| Linseed "Cake Meal .....                | 11.8   | 35.7     | 3.1  | 33.9               | 9.0    | 6.5  |
| Maize Germ Cake .....                   | 9.5    | 15.1     | 6.9  | 57.9               | 5.3    | 5.3  |
| "    Meal .....                         | 10.5   | 23.1     | 11.7 | 49.8               | 5.4    | 1.0  |
| Palm "Nut kernel Cake, English          | 11.6   | 17.1     | 6.3  | 48.4               | 12.8   | 3.8  |
| "    Imported .....                     | 9.7    | 16.6     | 10.2 | 38.2               | 21.3   | 4.0  |
| "    Extracted .....                    | 15.0   | 19.0     | 2.0  | 51.0               | 9.0    | 4.0  |
| Soya Bean Cake .....                    | 14.5   | 42.4     | 7.0  | 25.8               | 5.0    | 5.3  |
| "    Meal, Extracted..                  | 11.3   | 44.7     | 1.5  | 31.9               | 5.1    | 5.5  |
| <b>Bye Products.</b>                    |        |          |      |                    |        |      |
| Barley, Brewer's Grains, Fresh          | 67.6   | 7.5      | 2.8  | 14.6               | 6.1    | 1.4  |
| "    Dried .....                        | 10.3   | 18.3     | 6.4  | 45.9               | 15.2   | 3.9  |
| "    Distiller's Grains, Fresh          | 73.8   | 8.4      | 3.0  | 10.4               | 3.6    | 0.8  |
| "    Dried .....                        | 8.0    | 27.7     | 11.6 | 40.8               | 10.1   | 1.8  |
| Maize, Gluten "Feed .....               | 7.8    | 24.0     | 10.9 | 51.2               | 5.3    | 1.1  |
| "    Gluten Meal .....                  | 8.2    | 29.3     | 11.8 | 46.5               | 3.3    | 0.9  |
| <b>Wheat Offals :</b>                   |        |          |      |                    |        |      |
| <i>Pure Grades.</i>                     |        |          |      |                    |        |      |
| Finest Grade, Fine Middlings..          | 12.7   | 15.7     | 3.4  | 64.0               | 1.8    | 2.4  |
| Second, Coarse Middlings or<br>Sharps.. | 13.5   | 16.4     | 5.0  | 56.2               | 5.3    | 3.6  |
| Third, Pollards .....                   | 13.3   | 14.3     | 4.8  | 55.6               | 7.7    | 4.3  |
| Fourth, Bran .....                      | 13.6   | 13.5     | 3.9  | 53.0               | 10.6   | 5.4  |
| <i>Mixed Grades.</i>                    |        |          |      |                    |        |      |
| 1st & 2nd Grades Mixed.                 |        |          |      |                    |        |      |
| Straight Run Middlings                  | 13.1   | 16.0     | 4.5  | 59.6               | 3.9    | 2.9  |
| 2nd & 3rd " Pollards..                  | 13.7   | 16.3     | 5.3  | 54.5               | 6.2    | 4.0  |
| 1st 2nd & 3rd " Offals..                | 13.8   | 15.7     | 4.7  | 58.0               | 4.5    | 3.3  |
| Yeasts, Dried .....                     | 12.1   | 49.3     | 2.9  | 30.4               | 0.1    | 5.2  |

## METHODS USED IN AMERICAN PRACTICE.

ALICE H. ATACK, M.A.

In case the Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists (A.O.A.C.) differ from the preceding British methods, a summary of the differences is given below, with additional notes.

A complete list of State Agricultural Colleges and Experiment Stations may be obtained from the U.S. Department of Agriculture, Washington, D.C.

A list of the Dominion Experimental Farms may be obtained from the Director, Experimental Farm, Ottawa, Canada.

### Soil Analysis.

*Sampling.* Owing to the variations in the composition of the soil at different depths, it is essential that samples should always be taken to the same depth, and with a tool making a clean vertical cut. The American method is to take samples which will be representative of the average depth of typically surface soil, usually about 7 ins., also composite samples from each distinctly different soil stratum to a depth of 40 ins., using a soil tube or auger, whichever may be best suited to the particular type of soil. It is recommended that the weight of a given volume of soil, as it lies in the field, be taken for calculating the percentage results obtained by analysis to pounds per given area of soil. Five or six points should be sampled along lines crossing the field in order to obtain as representative a sample as possible. The samples of each depth should then be thoroughly mixed and dried at ordinary temperature in a well-aired place. The dried soil is then pulverised to pass through a 1 mm. sieve, using a porcelain pebble mill or other suitable method which does not reduce the rock fragments. The sifted material is thoroughly mixed and preserved in a stoppered container. The detritus is weighed and discarded.

*Organic matter.* Special apparatus for estimating organic carbon is given in A.O.A.C.

*Nitrates.* The following methods are quoted from A.O.A.C. The solution is prepared by weighing 100 gm. of air-dried soil into a mortar or porcelain evaporating dish and adding with constant stirring 1 gm. of lime and 200 cc. of water,

After allowing to settle for 10—20 mins., the mixture is filtered, a clear filtrate being essential.

In case the filtrate contains 6 parts or less of chlorine per million, procedure (A) is used ; otherwise procedure (B) is used.

(A) The reagents necessary are :

Phenol disulphonic acid solution. 25 grm. of pure white phenol is dissolved in 150 cc. of concentrated sulphuric acid, 75 cc. of fuming sulphuric acid (13—15 per cent.  $\text{SO}_3$ ) added, and the mixture heated at  $100^\circ\text{C}$ . for 2 hrs.

Standard nitrate solution. 0.722 grm. of pure potassium nitrate is dissolved in 1 litre of nitrate-free water. 50 cc. of the nitrate solution is evaporated to dryness in a porcelain dish and treated with 2 cc. of the phenol disulphonic acid solution, rubbing with a glass rod to insure intimate contact. After diluting to 500 cc., 1 cc. is equivalent to 0.01 mgrm. of nitrogen as nitrate. This solution is stable, and standards for comparison are prepared by adding ammonium hydroxide solution to measured volumes of it contained in 100 cc. Nessler tubes.

25 cc. of the solution from the soil, prepared as above, is evaporated on a water-bath, allowed to cool, and 2 cc. of the phenol disulphonic acid solution added. After tritulating thoroughly with a glass rod, 25 cc. of water is added, and then concentrated ammonium hydroxide or potassium hydroxide, drop by drop, with constant stirring, until a permanent yellow colour is obtained. The solution is compared in a colorimeter with the standard solution prepared in a similar manner as above.

(B) The reagents necessary are :

Aluminium foil (pure), cut into strips about 10 cm. long, weighing about 0.5 grm.

Sodium or potassium hydroxide solution. 250 grm. of pure hydroxide is dissolved in 1250 cc. of water, and two or three strips of aluminium foil added ; after allowing to stand about 12 hrs., the solution is concentrated to 1 litre.

25 cc. of the solution from the soil, prepared as above, or such quantity as contains 0.1 mgrm. or less of nitrogen in the form of nitrate is placed in a 300 cc. casserole. 2 cc. of the sodium hydroxide solution is added, and the mixture is concentrated to about one-third of the original volume and then transferred to a 100 cc. test-tube, using nitrogen-free water and diluting, if necessary, to about 75 cc. A blank is



prepared from 75 cc. of nitrogen-free water and 2 cc. of the sodium hydroxide solution in a 100 cc. test-tube. A strip of aluminium foil is placed in the test-tubes containing the sample and the blank, and the test-tubes are then closed with rubber stoppers and connected with other test-tubes containing about 50 cc. of slightly acidified ammonia-free water. After allowing sample and blank to stand for 12 hrs. at room temperature, or until reduction is complete, the traps are tested with Nessler solution; if the traps contain the equivalent of only 1-2 cc. of standard ammonia solution, they should be disregarded; if high in ammonia, indicated by frothing over of the sample, the determination should be discarded. Sample and blank are transferred to distilling flasks, using 250 cc. of ammonia-free water for each, and the distillates examined with Nessler solution and compared with standards. After necessary correction for the blank, the mgrm. per litre of nitrogen in the form of nitrate is calculated.

*Carbonates.* Special apparatus for the determination is given in A.O.A.C.

*Mineral substances.* Directions for sodium carbonate fusion of the soil, prior to the determination of silica, etc., are given in A.O.A.C.

*Available phosphoric acid.* There is still considerable controversy as to the practical value of methods for estimating available phosphoric acid in soils. A.O.A.C. recommends a neutral solution of ammonium citrate as solvent in preference to citric acid. Fraps suggests 2N nitric acid (*J. Ind. Eng. Chem.*, vol. ii, No. 8, pp. 350—352). See also *Soil Science*, vol. xiii, No. 5, pp. 355—396.

*Alkali salts.* In semi-arid districts, soluble salts formed by decomposition of rock tend to accumulate and may reach toxic quantities; hence soils from such areas should be tested for saline material. The most common and dangerous "alkali salts" found in the U.S.A. are sodium chloride, carbonate and sulphate, and magnesium sulphate; large amounts of calcium sulphate are often associated with the other salts, but this seems to be harmless to plants, and experiments seem to show that its presence decreases the deleterious effects of magnesium sulphate. Sodium carbonate is the chief constituent of "black alkali," and when present in amount exceeding 0.05—0.1% not only tends to corrode the plant just at the surface of the ground, but also destroys the granular structure of the soil by deflocculating the clay; the toxic effect of sodium bi-carbonate, however, is comparatively slight.



The most convenient method for rapidly estimating the "alkali" content is to use the electric bridge described in the *U.S. Bureau of Soils Bulletin*, No. 61. In case this instrument indicates that the "alkali" content is approaching the limits of toxicity, a complete analysis of the saline material should be made before releasing or condemning the soil for agricultural purposes.

The solution is prepared by shaking 25 grm. of the soil with 500 cc. of distilled water for 3 hrs. The filtrate is then analysed for calcium, magnesium, sodium, chlorides, sulphates, and carbonates.

For purposes of calculation, it is usual to assume that all the chloride is present in the form of sodium chloride. The sulphate present is then calculated as sodium sulphate, and the remaining sodium as sodium carbonate. In case calcium or magnesium are present in the solution, it will be found that there is an excess of sulphate present over that necessary to combine with the sodium; this remaining sulphate is then calculated as calcium sulphate, and the remainder as magnesium sulphate in case magnesium is also present. Calcium or magnesium sulphate is rarely found if sodium carbonate is present, as in such cases any calcium or magnesium in the soil would be in the form of insoluble carbonates.

For a detailed discussion of the limits of toxicity, the book by Dr. Harris on "Soil Alkali" should be consulted. Under normal conditions, the following appear to be the limits for ordinary farm crops: sodium carbonate, 0.05—0.1%; sodium chloride, 0.1—0.2%; sodium sulphate and magnesium sulphate, 0.7—1.0%.

*Mechanical analysis.* A full description of the apparatus used for the mechanical analysis of soils by the U.S. Department of Agriculture is given in *Bureau of Soils Bulletin*, No. 84.

The U.S. Bureau of Soils has adopted the following limits of mechanical grades:—

|                |                   |
|----------------|-------------------|
| Fine gravel    | 2 — 1 mm.         |
| Coarse sand    | 1 — 0.5 „         |
| Medium sand    | 0.5 — 0.25 „      |
| Fine sand      | 0.25 — 0.10 „     |
| Very fine sand | 0.10 — 0.05 „     |
| Silt           | 0.05 — 0.005 „    |
| Clay           | less than 0.005 „ |

The sample is air-dried, and after mixing thoroughly a subsample is taken by quartering; this is sifted through a 2 mm. sieve, any lumps present are crushed with a wooden rolling pin,

care being taken not to crush any gravel into sand. The material passing through the sieve is dried at 100°C. for 2 hrs. in a flat-bottomed aluminium dish, allowed to cool in a dessicator, and a representative 5 gm. sample weighed out. This is placed in an 8 oz. sterilizer bottle, covered with 2 oz. of distilled water and about 5 drops of ammonia. A number of the sterilizer bottles are then placed in trays in a mechanical shaker for 7 hrs.; longer or too vigorous shaking may erode the rubber stoppers and affect the analysis. The bottles are then removed from the shaking machine and placed upright in a rack, any material adhering to the stoppers being washed back. Each of the soils is in turn brought into suspension by using a compressed water jet containing a small percentage of ammonia. When sufficient time has been allowed for the sand to settle, as shown by examining a drop of the liquid under the microscope, the supernatant liquid is poured off from the sterilizer bottle into a centrifuge tube. The sample is then centrifuged until no silt is left in suspension, as shown by examination under the microscope. The clay suspension is then poured into a large container, and the silt at the bottom of the tube again brought into suspension by means of the water-jet and centrifuged as before. This process is repeated until the water above the silt is clear after centrifuging. The number of washings necessary depends upon the amount of clay present; large amounts of clay are difficult to separate, although no separation is absolutely complete.

The sand separated above is transferred from the sterilizer bottle to a small platinum dish, dried on the steam-bath and then in an electric oven at 100°C., allowed to cool, and weighed. The sand is then separated by standard sieves into the five grades. The silt is transferred from the centrifuge tube to a platinum dish, dried and weighed. The clay may be determined either directly or indirectly, *i.e.*, by evaporating the liquid and actually weighing the residue, or by deducting the weight of silt *plus* sand from the total weight of the sample.

In making a mechanical analysis, the organic content of the soil is disregarded, as there is no satisfactory method of separating the organic matter without altering the soil structure or dehydrating the clay. The clay being usually equally divided among the different separates, this only causes a small error in the analysis of ordinary soils. It is evident, however, that little reliance can be placed upon the results of an analysis in the case of soils containing very high percentages of organic matter.

# PERCENTAGE COMPOSITION OF AMERICAN SOILS. (Abstr. U.S. Dept. Agric. Bull. 122.)

Nos. 1 and 2. Sand and loam. Coastal Plains province, viz.: Alabama, Florida, Louisiana, Mississippi, North Carolina, South Carolina, Texas, Virginia, Georgia, Oklahoma, Maryland, New Jersey.  
 Nos. 3-6. Loam and clay loam. Limestone Valley and Uplands province, viz.: Alabama, Tennessee, Arkansas, Missouri, Pennsylvania, Virginia, Kentucky, West Virginia.  
 Nos. 7-14. Silt loam. Glacial and Loessial province, viz.: Illinois, Indiana, Iowa, Kansas, Nebraska, Wisconsin, Kentucky, Ohio, Minnesota, New York, New Jersey, Maine.  
 Nos. 15-26. Clay, sandy loam, silt loam. Piedmont Plateau province, viz.: Alabama, Georgia, North Carolina, South Carolina, Virginia, Pennsylvania.

| No. | SiO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | Fe <sub>2</sub> O <sub>3</sub> | MnO   | CaO  | MgO  | K <sub>2</sub> O | P <sub>2</sub> O <sub>5</sub> | SO <sub>3</sub> | Ignition loss. | Water at 110°. | Organic matter |
|-----|------------------|--------------------------------|--------------------------------|-------|------|------|------------------|-------------------------------|-----------------|----------------|----------------|----------------|
| 1   | 94.50            | 2.07                           | 0.83                           | 0.007 | 0.39 | 0.09 | 0.10             | 0.06                          | 0.07            | 1.74           | 0.48           | 1.13           |
| 2   | 85.30            | 8.82                           | 1.91                           | 0.004 | 0.38 | 0.19 | 0.12             | 0.04                          | 0.13            | 3.22           | 1.48           | 0.29           |
| 3   | 79.35            | 8.89                           | 4.44                           | 0.070 | 0.63 | 0.39 | 0.67             | 0.18                          | 0.13            | 4.80           | 1.99           | 1.96           |
| 4   | 74.81            | 12.80                          | 5.28                           | 0.053 | 0.40 | 0.33 | 0.75             | 0.15                          | 0.19            | 4.63           | 2.38           | 0.93           |
| 5   | 70.99            | 11.39                          | 4.23                           | 0.180 | 0.93 | 1.08 | 2.71             | 0.19                          | 0.39            | 6.08           | 1.61           | 2.87           |
| 6   | 66.49            | 14.80                          | 5.99                           | 0.100 | 0.35 | 1.93 | 3.58             | 0.16                          | 0.14            | 5.06           | 1.40           | 0.82           |
| 7   | 75.12            | 10.49                          | 4.13                           | 0.022 | 0.49 | 0.48 | 1.40             | 0.18                          | 0.09            | 4.44           | 2.03           | 2.43           |
| 8   | 74.64            | 12.26                          | 5.01                           | 0.036 | 0.37 | 0.90 | 1.99             | 0.15                          | 0.10            | 3.59           | 1.28           | 0.60           |
| 9   | 73.61            | 9.67                           | 3.54                           | 0.120 | 1.08 | 0.77 | 2.28             | 0.22                          | 0.17            | 7.44           | 2.94           | 4.29           |
| 10  | 71.43            | 13.44                          | 4.28                           | 0.104 | 1.40 | 1.28 | 2.03             | 0.16                          | 0.14            | 5.56           | 4.12           | 2.72           |
| 11  | 65.68            | 14.15                          | 5.67                           | 0.068 | 1.36 | 0.83 | 2.16             | 0.15                          | 0.17            | 9.52           | 3.39           | 7.07           |
| 12  | 73.80            | 13.24                          | 4.37                           | 0.072 | 1.19 | 0.39 | 2.22             | 0.11                          | 0.03            | 3.13           | 1.18           | 1.39           |
| 13  | 73.50            | 9.10                           | 4.30                           | 0.113 | 0.94 | 0.71 | 2.03             | 0.24                          | 0.13            | 7.70           | 2.75           | 4.94           |
| 14  | 76.86            | 9.49                           | 3.79                           | 0.062 | 0.93 | 0.58 | 1.04             | 0.20                          | 0.18            | 4.76           | 2.03           | 2.62           |
| 15  | 66.49            | 17.11                          | 7.43                           | 0.51  | 0.36 | 0.31 | 0.62             | 0.17                          | 0.07            | 8.06           | 2.47           | 1.26           |
| 16  | 44.15            | 27.58                          | 16.23                          | 0.033 | 0.44 | 0.09 | 0.61             | 0.15                          | 0.07            | 11.83          | 2.90           | 0.27           |
| 17  | 88.57            | 5.76                           | 1.55                           | 0.044 | 0.39 | 0.21 | 0.82             | 0.08                          | 0.04            | 2.93           | 0.53           | 1.46           |
| 18  | 55.69            | 24.42                          | 8.83                           | 0.022 | 0.40 | 0.29 | 1.06             | 0.07                          | 0.09            | 8.94           | 2.00           | 0.09           |
| 19  | 80.79            | 10.55                          | 1.61                           | 0.017 | 0.89 | 0.19 | 3.96             | 0.12                          | 0.06            | 1.41           | 0.48           | 0.40           |
| 20  | 69.35            | 18.04                          | 3.42                           | 0.014 | 0.72 | 0.29 | 3.34             | 0.12                          | 0.06            | 4.54           | 1.53           | 0.33           |
| 21  | 76.71            | 12.85                          | 2.81                           | 0.005 | 0.08 | 0.29 | 3.26             | 0.05                          | 0.12            | 3.16           | 0.47           | 1.78           |
| 22  | 74.38            | 16.31                          | 2.56                           | 0.005 | 0.21 | 0.38 | 4.07             | 0.05                          | 0.14            | 2.80           | 0.22           | 0.41           |
| 23  | 84.58            | 5.54                           | 3.30                           | 0.045 | 0.21 | 0.25 | 0.74             | 0.12                          | 0.15            | 3.89           | 0.92           | 2.40           |
| 24  | 74.99            | 10.90                          | 6.75                           | 0.039 | 0.26 | 0.32 | 0.97             | 0.15                          | 0.16            | 4.72           | 1.43           | 1.04           |
| 25  | 74.33            | 11.00                          | 4.64                           | 0.136 | 1.13 | 0.69 | 1.57             | 0.16                          | 0.15            | 4.51           | 1.72           | 1.99           |
| 26  | 71.76            | 14.36                          | 5.82                           | 0.109 | 1.73 | 1.06 | 1.50             | 0.10                          | 0.10            | 2.83           | 2.06           | 1.21           |

## Analysis of Manures.

*Determination of nitrogen in nitrates.* 5 grm. of the nitrate is placed in a 500—700 cc. flask with 200 cc. water, 5 grm. of powdered zinc, 1-2 grm. ferrous sulphate, and 50 cc. of sodium hydroxide solution (36° Baumé). The flask is connected with a distilling apparatus and distilled into standard sulphuric acid, which is then titrated with alkali, using methyl red or cochineal as indicator.

Alternative methods and methods for the estimation of water-insoluble organic nitrogen are given in A.O.A.C.

### *Determination of phosphates.*

(a) Phosphates soluble in water. 2 grm. of the sample is placed on a 9 cm. filter paper and washed with successive small portions of water, allowing each portion to pass through before adding more, until the filtrate measures about 250 cc. If the filtrate is turbid a small amount of nitric acid is added. The solution is then made up to a convenient volume, and an aliquot portion used for the determination of the phosphoric acid by the molybdate method, as described below.

(b) Phosphates insoluble in ammonium citrate. The ammonium citrate solution is prepared as follows: 370 grm. of commercial citric acid is dissolved in 1500 cc. of water; the solution is then nearly neutralized with ammonium hydroxide, allowed to cool, and made exactly neutral to corallin (saturated alcoholic solution) by adding dilute ammonium hydroxide very slowly. The solution is then diluted to Sp. Gr. 1.09 at 20°C. The soil is digested in this solution as follows: 100 cc. of the citrate solution is heated to 65°C. in a 250 cc. flask, placed in a warm water-bath and covered loosely to prevent free evaporation. The filter containing the washed residue from (a) is dropped into the flask, which is then closed tightly with a rubber cork and shaken violently until the filter paper is reduced to pulp, relieving the pressure by momentarily removing the stopper. The sample is digested at 65°C. for exactly 30 mins., shaking every 5 mins. The contents of the flask are then filtered as quickly as possible, and the filter washed with water at 65°C. until the volume of the filtrate is 350 cc. The filter and its contents are transferred to a crucible, and ignited to remove all organic matter; the residue is then digested with 10—16 cc. of concentrated hydrochloric acid until all the phosphate is dissolved.

The solution is diluted to 200 cc., filtered through a dry filter, and an aliquot portion used for the phosphoric acid determination by the molybdate method as below.

(c) Total phosphoric acid. 2 gm. of the sample is ignited to expel any organic matter present, and the residue dissolved in hydrochloric acid; any silica present must be removed. The solution is then diluted to 200 cc., and poured through a dry filter. An aliquot portion of the solution corresponding to 0.25 gm., 0.50 gm., or 1 gm. is used for the phosphoric acid determination by the molybdate method.

(d) Molybdate method. An aliquot portion of the solution prepared as in (a), (b) or (c) is neutralized with ammonium hydroxide and cleared by addition of a few drops of nitric acid. In case hydrochloric acid or sulphuric acid has been used as a solvent 15 gm. of dry ammonium nitrate should be added. The solution is then heated to about 65°C., and molybdate solution added (70 cc. for each 0.1 gm. phosphoric acid present), digesting at this temperature for 1 hr. The phosphoric acid has been completely precipitated if the supernatant liquid remains clear on the addition of a few drops of molybdate solution. The precipitate is filtered, washed with ammonium nitrate solution, and dissolved by washing into a beaker with 100 cc. of warm water containing sufficient ammonium hydroxide. This solution is nearly neutralized with hydrochloric acid, allowed to cool, and magnesia mixture is added slowly from a burette with vigorous stirring (15 cc. of magnesia mixture for each 0.7 gm. phosphoric acid present). After 15 mins., 12 cc. of ammonium hydroxide (Sp. Gr. 0.90) is added, and the beaker allowed to stand until the supernatant liquid is clear. The precipitate is filtered, washed with dilute ammonium hydroxide until the washings are practically free from chlorides, ignited, and weighed as magnesium pyrophosphate.

The solutions used in the above method should be prepared as follows:

Molybdate solution. 100 gm. of molybdic acid is dissolved in a mixture of 144 cc. of ammonium hydroxide (Sp. Gr. 0.90) and 271 cc. of water. This solution is poured slowly and with constant stirring into a mixture of 489 cc. of nitric acid (Sp. Gr. 1.42) and 1148 cc. of water. The mixture is kept in a warm place for several days, decanted from any sediment, and preserved in glass-stoppered bottles.

Ammonium nitrate solution. 200 gm. of commercial ammonium nitrate, phosphate free, is dissolved in water and diluted to 2 litres.

Magnesia mixture. 22 gm. of recently ignited calcined

magnesia is dissolved in dilute hydrochloric acid, avoiding an excess of the acid. A small excess of calcined magnesia is added, and the mixture boiled for a few minutes to precipitate any iron, aluminium or phosphoric acid. After filtering, 280 grm. of ammonium chloride and 261 cc. of ammonium hydroxide (Sp. Gr. 0.90) are added, and the solution diluted to 2 litres.

Dilute ammonium hydroxide for washing should consist of 100 cc. of ammonium hydroxide (Sp. Gr. 0.90) diluted to 1 litre.

## Analysis of Feeding Stuffs.

### *Preparation of sample.*

The sample is ground so that it will pass through a sieve having circular openings 1 mm. in diameter; if the material cannot be ground it must be reduced to as fine a state as possible.

### *Determination of moisture.*

A quantity representing about 2 grm. of the dried material is dried *in vacuo* at 100°C. to constant weight (approximately 5 hrs.). Directions for drying *in vacuo* without heating are given in A.O.A.C.

### *Determination of oil.*

Large quantities of soluble carbohydrates in the material may interfere with the complete extraction of the fat, and should therefore be extracted with water before proceeding with the determination. 2 grm. of the material is extracted with washed, redistilled ether in a Soxhlet apparatus for 16 hrs. The extract is dried at 100°C. for 30 mins., allowed to cool in a dessicator, and weighed. The drying for 30 mins. and weighing is continued alternately until a constant weight is reached, which for most materials requires a period of 1-1½ hrs.

*Carbohydrates.* Methods for the determination of sugars are given in detail in A.O.A.C.

---



## DAIRY PRODUCTS.

G. D. ELSDON, B.Sc., F.I.C., and A. DOUGLAS HEYWOOD, F.I.C.

### Examination and Analysis of Milk.

The average composition of genuine cows' milk is as follows:—87·35% water, 3·75% fat, 8·90% solids-not-fat. The percentage of solids-not-fat generally consists of: milk sugar, 4·7; casein, 3·0; albumen, 0·4; ash, 0·75; other constituents, 0·05. The maximum and minimum figures recorded for fats are 12·52% and 1·04%; for solids-not-fat 10·60% and 4·90%.

Figures showing the average composition of milk have been given by Richmond in the *Analyst* for many years up to 1914 (see also *Analyst*, 1917, **42**, 118; 1920, **45**, 138). For Egyptian cow's milk, see Hogan and Azadian (*Ibid.*, 1919, **44**, 168). For the composition of buttermilk, see Hodgson (*Ibid.*, 1919, **44**, 229).

The evening milk usually contains 0·2—0·7% more fat than the morning milk; the fat is usually at its lowest in May and June, and at its highest in November; the solids-not-fat are usually somewhat lower in July and August. The relationship of milk sugar to proteins (casein and albumen) and to ash in genuine normal milk generally approaches the ratio 13 : 9 : 2.

### CORRECTION OF SPECIFIC GRAVITY OF MILK FOR TEMPERATURE (Chr. Müller).

| Sp. Gr.<br>(Water<br>=1000). | Temperature of Milk °C. |      |      |      |      |      |      |      |      |      |      |
|------------------------------|-------------------------|------|------|------|------|------|------|------|------|------|------|
|                              | 10                      | 11   | 12   | 13   | 14   | 15   | 16   | 17   | 18   | 19   | 20   |
| 1014                         | 13.4                    | 13.5 | 13.6 | 13.7 | 13.8 | 14.0 | 14.1 | 14.2 | 14.4 | 14.6 | 14.8 |
| 15                           | 14.4                    | 14.5 | 14.6 | 14.7 | 14.8 | 15.0 | 15.1 | 15.2 | 15.4 | 15.6 | 15.8 |
| 16                           | 15.4                    | 15.5 | 15.6 | 15.7 | 15.8 | 16.0 | 16.1 | 16.3 | 16.5 | 16.7 | 16.9 |
| 17                           | 16.4                    | 16.5 | 16.6 | 16.7 | 16.8 | 17.0 | 17.1 | 17.3 | 17.5 | 17.7 | 17.9 |
| 18                           | 17.4                    | 17.5 | 17.6 | 17.7 | 17.8 | 18.0 | 18.1 | 18.3 | 18.5 | 18.7 | 18.9 |
| 19                           | 18.4                    | 18.5 | 18.6 | 18.7 | 18.8 | 19.0 | 19.1 | 19.3 | 19.5 | 19.7 | 19.9 |
| 20                           | 19.3                    | 19.4 | 19.5 | 19.6 | 19.8 | 20.0 | 20.1 | 20.3 | 20.5 | 20.7 | 20.9 |
| 21                           | 20.3                    | 20.4 | 20.5 | 20.6 | 20.8 | 21.0 | 21.2 | 21.4 | 21.6 | 21.8 | 22.0 |
| 22                           | 21.3                    | 21.4 | 21.5 | 21.6 | 21.8 | 22.0 | 22.2 | 22.4 | 22.6 | 22.8 | 23.0 |
| 23                           | 22.3                    | 22.4 | 22.5 | 22.6 | 22.8 | 23.0 | 23.2 | 23.4 | 23.6 | 23.8 | 24.0 |
| 24                           | 23.3                    | 23.4 | 23.5 | 23.6 | 23.8 | 24.0 | 24.2 | 24.4 | 24.6 | 24.8 | 25.0 |
| 25                           | 24.2                    | 24.3 | 24.5 | 24.6 | 24.8 | 25.0 | 25.2 | 25.4 | 25.6 | 25.8 | 26.0 |
| 26                           | 25.2                    | 25.3 | 25.5 | 25.6 | 25.8 | 26.0 | 26.2 | 26.4 | 26.6 | 26.9 | 27.1 |
| 27                           | 26.2                    | 26.3 | 26.5 | 26.6 | 26.8 | 27.0 | 27.2 | 27.4 | 27.6 | 27.9 | 28.2 |
| 28                           | 27.1                    | 27.2 | 27.4 | 27.5 | 27.8 | 28.0 | 28.2 | 28.4 | 28.6 | 28.9 | 29.2 |
| 29                           | 28.1                    | 28.2 | 28.4 | 28.6 | 28.8 | 29.0 | 29.2 | 29.4 | 29.6 | 29.9 | 30.2 |
| 30                           | 29.0                    | 29.2 | 29.4 | 29.6 | 29.8 | 30.0 | 30.2 | 30.4 | 30.6 | 30.9 | 31.2 |
| 31                           | 30.0                    | 30.2 | 30.4 | 30.6 | 30.8 | 31.0 | 31.2 | 31.4 | 31.7 | 32.0 | 32.3 |
| 32                           | 31.0                    | 31.2 | 31.4 | 31.6 | 31.8 | 32.0 | 32.2 | 32.4 | 32.7 | 33.0 | 33.3 |
| 33                           | 32.0                    | 32.2 | 32.4 | 32.6 | 32.8 | 33.0 | 33.2 | 33.4 | 33.7 | 34.0 | 34.3 |
| 34                           | 32.9                    | 33.1 | 33.4 | 33.5 | 33.8 | 34.0 | 34.2 | 34.4 | 34.7 | 35.0 | 35.3 |
| 35                           | 33.8                    | 34.0 | 34.2 | 34.4 | 34.7 | 35.0 | 35.2 | 35.4 | 35.7 | 36.0 | 36.3 |



### *Specific gravity.*

This may be determined by means of a delicate hydrometer or a Westphal balance. The specific gravity of genuine milk generally falls between 1.029 and 1.034 at 15.5°C. In case the gravity be taken at another temperature, it may be corrected by means of the above table. In correcting specific gravity for temperature it is generally sufficient to add or subtract 0.0002 for each degree over or under 15°C.

The samples should be shaken gently just before taking the specific gravity, in order to mix in the cream, but care must be taken to avoid the formation of air bubbles.

The specific gravity of milk is raised by the abstraction of fat, and lowered by the addition of water; hence by partial skimming and watering an adulterated sample may possess the same gravity as that of genuine milk. It is therefore necessary to estimate the fat and total solids.

### **Determination of total solids and ash**

About 5 gm. of milk are measured out into a weighed platinum or porcelain dish from a pipette, and the whole is again rapidly weighed. The dish is placed on a boiling water bath until the solids are apparently dry, and then heated in the water-oven for three hours, cooled in the desiccator and weighed to obtain the total solids.

The ash is preferably estimated on at least 10 gm. of the milk. The solids are ignited at as low a temperature as possible, the flame (*e.g.* a luminous Argand burner) being placed some distance below the dish, to avoid volatilisation of chlorides.

When the milk is sour it should be neutralised to phenolphthalein with N/10 caustic soda or strontia before evaporation, the weight of solids being corrected for the amount of alkali added. The total solids will be low on account of the production of volatile products during the decomposition, but suitable corrections may be made (see Richmond and Miller, *Analyst*, 1906, **31**, 317; Richmond, "Dairy Chemistry," 2nd edition, p. 319; compare also the maceration method for fat, below).

### **Determination of fat.**

*Adams' method.* A pipette is graduated to deliver 5 gm. of milk (Sp. Gr. 1.032) on draining for 45 secs.; such a pipette would deliver 4.82 gm. of water. In actual practice the amount of any particular milk delivered is usually weighed in the estimation of the total solids, and if it differs materially from 5 gm. the difference may be allowed for. 5 gm. of the milk are delivered from the pipette on to the special "Adams' coil," which is then allowed to dry in the air overnight (Richmond recommends drying in the water-oven). The coil is rolled up and placed in a Soxhlet extractor fitted

with a double surface condenser and with a small tared flask. Ether is then poured into the Soxhlet tube until there is rather more than necessary to syphon over, and the flask gently heated on the water-bath for  $2\frac{1}{2}$  hrs. At the end of this time, when the ether has just syphoned over into the flask, the coil is removed from the tube, the distillation continued, and all the ether allowed to collect in the tube, as there is not sufficient ether to fill up to the top of the syphon when the coil is removed. The flask is then removed, and a few drops of ether and of absolute alcohol added, after which it is dried in the steam-oven for  $1\frac{1}{2}$  hrs. and weighed. The coils themselves give a slight residue; this is estimated on several coils out of each delivery and subtracted from the weight of fat obtained. Before use the coils should be extracted for at least half an hour with ether. In the case of coils which are not sold as "fat-free" they should be extracted for 3 hrs. with alcohol containing 10% of acetic acid, and then the flask changed and the coils extracted for half an hour with alcohol, placing a small quantity of anhydrous sodium carbonate in the flask; a further extraction for half an hour with ether is an advantage.

The Adams' method is unsuitable for sour milk.

*The Gerber method.* This process requires special apparatus, including a special type of centrifuge and tubes. 10 cc. of sulphuric acid (Sp. Gr. 1.820—1.825) are measured into one of the butyrometer tubes, and then 11 cc. of the milk allowed to run down the sides of the butyrometer and to float on the surface of the acid; the pipette is allowed to drain 4 secs., and then touched on the surface of the liquid or on the neck of the tube. 1 cc. of amyl alcohol is then added, the stopper inserted, and the butyrometer well shaken. The butyrometer is inverted two or three times, so that any acid in the neck may be thoroughly mixed with the liquid; it is then placed in water at  $70^{\circ}\text{C}$ . for 5 mins., when it is ready for whirling. The tube should be whirled for about 3 mins. at full speed, and not stopped suddenly. The tube is then placed in water at  $70^{\circ}\text{C}$ . for a few minutes before reading the volume of the fat, which is taken from the bottom of the upper meniscus to the separating line.

In calibrating the tubes 0.8 large divisions are equal to 0.1 cc. The pipette should deliver 11.02 grm. of water.

*The Röse-Gottlieb method.* A stoppered cylinder, or preferably a light flat-bottomed stoppered tube about 7 ins. long and of a uniform width of about 1 in. is weighed. 5 cc. of the milk are pipetted into it and again weighed. 0.5 cc. of 15% ammonia is added and mixed with the milk by rotating the tube. 5 cc. of alcohol (methylated spirit free from petroleum) are added, and the liquids well mixed by a rotary

motion, avoiding splashing on to the stopper. 12.5 cc. of ether are added in small quantities with constant rotary shaking as before, and then 12.5 cc. of petroleum ether (b.pt. below  $60^{\circ}\text{C}.$ ) introduced, and the stopper inserted loosely. The tube is then partially immersed in a water-bath at about  $60^{\circ}\text{C}.$  until ether begins to condense on the stopper when the tube is removed from the water-bath, the stopper inserted tightly, and the tube cooled under the tap and thoroughly shaken. When the liquid has separated into two perfectly clear layers the stopper is removed, wash-bottle tubes inserted, and the ether-layer blown off to within  $\frac{1}{8}$  in. into a small tared flask. 25 cc. of a mixture containing 50% ether and 50% petroleum ether are added, and the extraction repeated. In the case of an ordinary milk three such extractions are sufficient. The mixed ether solutions are evaporated, and the residue dried in the water-oven to a constant weight. The fat is then removed by washing several times with a small amount of petroleum ether and the flask again weighed, the loss being fat. The method may be used, taking suitable quantities, for ordinary milk, sour milk, condensed or dried milks (sweetened and unsweetened), cream and cheese.

*The Maceration method.* This process was originally devised by Bell. The method as modified by Richmond is substantially as follows, and is essentially the same. (*Analyst*, 1906, **31**, 317.)

About 10 grm. of milk are weighed into a flat-bottomed platinum basin, about 3 ins. diam. and slightly over 1 in. high, and provided with a flat-ended glass stirrer. Two drops of a 0.5% solution of phenolphthalein are added, and approximately N/11 strontia solution added until a faint pink colour appears. The contents are evaporated to a damp paste on the water-bath, when the basin is transferred to a hot plate, and the paste mixed with the stirrer; at a certain point in the evaporation, the paste detaches itself from the basin, and by careful manipulation both basin and stirrer can be obtained practically clean. On further evaporation with stirring the paste gradually attains a state in which it may be crushed, and at this stage it is removed from the hot plate and about 20 cc. of methylated ether (Sp. Gr. 0.720, dried over calcium chloride) are added. By gentle rubbing with the stirrer the solids are crushed; the basin and stirrer are now scraped with a spatula to bring any small portions of solids adhering to the sides under the ether, and the solids are gently rubbed to a powder. The ether is decanted through a weighed filter-paper, and the solids again treated with ether. The ethereal solution is allowed to settle, and the ether decanted through the filter. Without any

further addition of ether the solids are now ground to a very fine powder, with the small amount of ether in the basin, so that the larger portions remaining may more readily be seen. A further addition of ether is made, and the solids again ground; at this stage the solids take some minutes to settle sufficiently to allow the decantation of the ether. After about six or eight treatments in this manner the solids are allowed to dry in the air, the portions clinging to the stirrer and sides of the basin detached, and 5 cc. of alcohol and a few drops of water are added; the solids are well mixed with the alcohol, and the basin is placed on the hot plate and evaporated until the paste begins to break up, when the solids are again treated as before. A second treatment with alcohol and a further six to eight extractions with ether are given. The solids are dried in the air, and then in the water-oven to constant weight (0.00428 grm. is subtracted for the equivalent of each cc. of N/10 strontia used). The mixed ethereal solutions are distilled, and the residue weighed; the fat is extracted with petroleum ether, and the small insoluble residue subtracted from the total (the residue usually consists of phenolphthalein, and its weight may be neglected without appreciable error).

*Calculation of results.* The presence of fat in milk tends to lower its specific gravity, while the presence of solids not fat tends to raise it; therefore there must be a relation between the gravity, fat and total solids which will enable the third factor to be calculated if the other two are known.

Various formulæ have been used whereby one factor may be calculated when the other two are known. The formula of *Hehner and Richmond* is:—

$$T = 0.254G + 1.164F.$$

This has been modified by *Richmond* as follows:—

$$T = 0.25G + 1.2F + 0.14,$$

where  $T = \%$  total solids;  $G =$  specific gravity — 1000 (Sp. Gr. water = 1000);  $F = \%$  fat. The calculation may be performed from *Hehner and Richmond's* table or by means of *Richmond's* slide rule.

Further details on the calculation of results are given by *Harris* (*Analyst*, 1918, **43**, 263, 345, 375; 1919, **44**, 43, 314), *Richmond* (*Ibid.*, 1919, **44**, 200), and by *Hodgson* (*Ibid.*, 1920, **45**, 91).

### Determination of proteins.

*Kjeldahl's method.* 10 grm. of milk, 25 cc. of pure sulphuric acid, a small crystal of copper sulphate, and 10 grm. of potassium sulphate are placed in a *Kjeldahl* flask and the whole boiled until colourless. The solution is then cooled, diluted, and the ammonia determined by distillation in the usual manner. The number of cc. of N/10 hydrochloric acid

used, multiplied by 0.014, gives the percentage of nitrogen, or multiplied by 0.08932, gives the percentage of proteins. The Kjeldahl process is described in greater detail under "Ultimate Analysis."

**Aldehyde figure.** 10 cc. of milk, neutralised to phenolphthalein with caustic soda and then mixed with 2 cc. of 40% formaldehyde solution, is titrated until neutral with N/10 strontia. The acidity due to the formaldehyde (separately determined) is subtracted. The acidity developed by the formaldehyde, calculated as degrees, gives the aldehyde figure. The strontia figure is about 1.1 times that given by N/10 soda. The aldehyde figure from strontia multiplied by 0.170 gives percentage of proteins.

#### Determination of acidity.

10 cc. of milk are placed in a 100 cc. extraction flask with 10 cc. of water and 1 cc. of 0.5% phenolphthalein solution, and titrated with N/10 soda until a faint pink colour is obtained. This may be matched against the colour produced by 1 drop of a 0.01 per cent. solution of rosaniline acetate in 96% alcohol in the same amount of milk, etc. Each cc. of N. alkali used per litre of milk is called 1° of acidity.

#### Determination of milk sugar.

**Wiley's method.** 3 cc. of mercuric nitrate solution (prepared by dissolving 5 cc. of mercury in 96 cc. of strong nitric acid and diluting with an equal volume of water) are added to 100 cc. of milk, the liquid mixed thoroughly, filtered, and the rotation read in a 200 mm. tube.

$$\% \text{ anhydrous lactose} = \frac{\alpha}{1.11 \times G.} \times \frac{100 - (F \times 1.075 \times G)}{100}$$

where  $\alpha$  = observed rotation,  $G$  = Sp. Gr. of milk in lactometric degrees, and  $F$  = % of fat, or;

$$\% \text{ anhydrous lactose (approx.)} = \alpha \times 0.84.$$

**Reduction method.** 10 cc. of milk are made up to about 80 cc. with water, just neutralised with N/10 NaOH, and Fehling's solution A added drop by drop until a flocculent precipitate forms and settles, leaving a clear solution. The solution is then made up to 100.67 cc., well mixed, and filtered (the 0.67 cc. is to allow for the volume occupied by the proteins and fat). The process is then continued as described in the sections on carbohydrates (cf. *Analyst*, 1919, 44, 408).

$$\% \text{ anhydrous lactose (approx.)} = \text{CuO} \times 0.64.$$

#### Detection of colouring matters.

Aniline colours may be detected by the production of a pink colour on addition of concentrated hydrochloric acid to the milk. Vegetable dyes may be detected by making alkaline with sodium carbonate, and immersing a strip of filter paper. The filter paper may be tested as follows: after allowing to



stand overnight annatto gives a pink colour with one drop of concentrated sulphuric acid; methyl orange behaves in the same manner, but is bleached by stannous chloride solution.

The addition of colouring matter to milk is prohibited by Section 4 of the Milk and Dairies (Amendment) Act, 1922.

#### Detection and determination of boric acid.

*Detection.* A few drops of milk are placed in a depression in a spot plate, and one drop of turmeric tincture and a drop of dilute hydrochloric acid added. The tile is warmed on the water-bath until the milk is dry; in the presence of boric acid a pink colour will be developed.

*Determination.* 70 cc. of milk are added to 7 cc. of approx. 3N. NaOH in a 3 in. flat-bottomed platinum dish and evaporated on the water-bath, the skin which forms being periodically removed to the side. A flame is applied to the side of the dish, care being taken that the contents do not froth over; the ignition is completed at a high temperature until the ash is almost white. The dish is cooled, and 35 cc. of water are added and allowed to stand until the melt is disintegrated, when it is filtered into a 100 cc. flask. 5 cc. of approx. 3N. hydrochloric acid and 15 cc. of water are added to the dish and the solution again filtered through the same filter into the same flask. The dish is further treated with 4 cc. of 3N. hydrochloric acid and 16 cc. of water, and again filtered. To the mixed filtrates 7 cc. of calcium chloride solution (10%) and phenolphthalein are added, and then N/1 NaOH is added until a slight permanent pink coloration is produced. The liquid is diluted to the mark and filtered into a graduated cylinder. 80 cc. of the filtrate are made slightly acid to methyl orange with hydrochloric acid and boiled to eliminate carbon dioxide. The solution is cooled and titrated with N/10 sodium hydroxide until neutral to methyl orange. 30 cc. of glycerol or 10 grm. of mannitol are added and the titration continued until the solution is neutral to phenolphthalein. The acidity due to 30 cc. of glycerol is determined and subtracted from the number of cc. of N/10 sodium hydroxide used after the addition of the glycerol; the difference multiplied by 0.011 gives the percentage of boric acid in the milk. In case the amount of sodium hydroxide used exceeds 1 cc., a portion of the boric acid will be precipitated together with the calcium phosphate. In this case the precipitate is washed with 25 cc. of water through a hole made in the filter paper, 5 cc. of 3N. hydrochloric acid, a further 25 cc. of water, 0.5 cc. of calcium chloride solution and phenolphthalein are added to the filtrate, and the liquid titrated with N. sodium hydroxide until just pink. The solution is diluted to 100 cc., filtered, and 80 cc. titrated as before. The amount of boric

acid so found is added to that found in the first precipitation after making the necessary correction for dilution.

*Richmond and Miller's method.* A mixture of 20 cc. of milk and 10 cc. of a 0.5% solution of phenolphthalein is titrated with N/10 caustic soda until pink, boiled, made faintly acid, and finally made faintly alkaline with N/10 caustic soda while still boiling. 30 cc. of glycerol are added, and the titration continued until the pink colour returns, without further heating. The number of cc. of N/10 caustic soda used (less that required by the glycerol) multiplied by 0.0031 gives the percentage of boric acid (*Analyst*, 1907, **32**, 151).

#### **Detection and estimation of formaldehyde.**

*Detection.* Hehner's reagent for the detection of formaldehyde is prepared by mixing 25 cc. of 5% ferric chloride solution and 1 litre of concentrated sulphuric acid. 2-3 cc. are placed in a small test-tube and about 5 cc. of the milk added carefully so that it forms a layer above the acid. In the presence of formaldehyde a violet coloration will be produced on standing. It has been stated that the presence of nitrites interferes with this reaction (*Analyst*, 1912, **37**, 155, 178), but Elsdon and Sutcliffe do not agree with this statement (*Analyst*, 1913, **38**, 452).

If the Gerber or Babcock method for the estimation of fat is used and ferric sulphate is added to the acid used, in proportion to the amounts indicated above, formaldehyde will produce a violet coloration on shaking the tube. If nitrates or nitrites are present, a bright golden-brown colour is produced (*Analyst*, 1913, **38**, 452). Nitrites may be detected by adding 1 or 2 cc. of Griess-Ilosvay solution (see "Special reagents") to 5 cc. of milk; a pink colour developing in less than a quarter of an hour indicates nitrites.

*Estimation.* In the method of Shrewsbury and Knapp (*Analyst*, 1909, **34**, 12), the reagent is made by mixing 100 cc. of concentrated hydrochloric acid with 1.6 cc. of N/1 nitric acid. 10 cc. of the freshly made reagent are added to 5 cc. of the milk in a test-tube, the mixture shaken vigorously and kept for 10 mins. in a water-bath at 50°, and then rapidly cooled. As the violet colour produced varies in intensity according to the amount of formaldehyde present, the formaldehyde may be estimated by comparison with standards. If the colour obtained is deeper than that shown by 6 parts of formaldehyde per million of milk, the sample should be diluted with pure milk. The most delicate quantitative reaction is obtained with milks containing 0.2 to 6 parts per million of formaldehyde. In case nitrites are present, 5 cc. of the milk are treated with 0.05 gm. of urea and 1 cc. of N/1 sulphuric acid, and the mixture heated in the boiling water-bath for 2 mins. and then cooled; the Shrewsbury and Knapp



method may then be performed in the usual way on the resulting liquid (Monier-Williams).

#### **Detection of salicylic acid.**

The milk is shaken with 10 vols. of water, filtered, and 1% ferric chloride solution is added drop by drop to the filtrate, when 0.01% of salicylic acid gives a brownish-purple colour.

#### **Detection and determination of benzoic acid.**

*Detection.* 25 cc. of milk are heated with an equal volume of hydrochloric acid until the precipitate is completely dissolved. The cooled mixture is shaken with 25 cc. of a mixture of two volumes of petroleum spirit and one volume of ether. The "ethereal" solution is separated and one drop of concentrated ammonia solution added. A precipitation of ammonium benzoate takes place in the "ethereal" solution if benzoic acid be present. As a confirmatory test 5 cc. of water are added to the "ethereal" solution, the mixture is shaken, the aqueous layer separated, heated for a few minutes on the water-bath to expel excess of ammonia, and tested for benzoic acid with ferric chloride in the usual manner.

*Determination.* 20—25 cc. of milk are heated with an equal volume of hydrochloric acid, under a reflux condenser if necessary. The cooled mixture is extracted three times with an equal volume of a mixture of equal parts of ether and petroleum spirit; the mixed separated "ethereal" layers are rendered alkaline with ammonia solution, 10 cc. of water added, and the mixture shaken; the aqueous layer is separated and the extraction repeated twice, keeping alkaline with ammonia if necessary. The mixed aqueous portions are made alkaline with hydrochloric acid, and extracted three times with 20 cc. of the mixture of ether and spirit as before. The final mixed "ethereal" solutions are allowed to evaporate spontaneously and dried in the desiccator until constant in weight. The benzoic acid is then driven off by heating to  $100^{\circ}\text{C}$ ., and the loss on heating gives the amount of benzoic acid present. (Hinks, *Analyst*, 1913, **38**, 555)

#### **Determination of sediment.**

The volume of sediment in milk may be estimated by placing about 500 cc. in a tall cylindrically-shaped vessel, to the bottom of which is attached a glass tube with its bottom end drawn out to a fine bore, such that 0.5 cc. occupies between 5 and 6 cm. of the tube, the tube being graduated in 100ths of a cc. The milk is allowed to stand for several hours, preferably overnight, with the addition of a small amount of formaldehyde to prevent the milk from souring; the volume of the sediment is then noted. A limit of not more than 2 vols. of sediment per 100,000 of milk has been suggested. If the volume of sediment is large, its nature

should be determined by means of the microscope (see Lowe, *Chemical News*, 1912, **105**, 61).

The presence of cow dung may be shown by Pettenkofer's test for bile salts, which is carried out as follows:—The sediment is removed to a watch-glass and stirred with a few drops of a solution of cane sugar, the whole being then dried on the water-bath. A drop of concentrated sulphuric acid added to the film will show a reddish-purple colour in the presence of bile salts.

### Adulteration of Milk.

Milk may be adulterated by the addition of water, the extraction of fat, or the addition of preservatives. If the fat falls below 3% or the solids-not-fat below 8.5%, adulteration is presumed, the proof to the contrary resting with the vendor (Sale of Milk Regulations, 1901). The Milk and Cream Regulations (1912 and 1917) prohibit the addition of any preservatives to milk. The "Milk (England and Wales) Order, 1921," states that dried or condensed milks may not be sold as "milk" after dilution with water, that "Grade A" (*i.e.*, milk of a special standard of hygienic quality) shall only be sold under license from the Ministry of Health, and that colouring matter or water shall not be added to milk or cream. The amending order (1920, No. 1056) states that "For the purposes of this Order the expression 'milk' shall include skimmed, separated and buttermilk, and any milk which has been submitted to any one or more of the following processes, *viz.*:—sterilization, pasteurization, homogenization, or any other like process, but shall not include condensed milk."

The Milk and Dairies (Amendment) Act, 1922, prohibits the addition of colouring matter or water or any dried or condensed milk or any fluid reconstituted therefrom or any skimmed milk or separated milk to milk intended for sale.

Richmond suggests a multiple standard of 8.5% of solids-not-fat: 4.5% of milk sugar, 0.5% of total nitrogen (=3.19% of proteins), and 0.70% of ash. Ash insoluble in hot water should not be less than 0.50%. "A milk should never be pronounced as watered on the evidence of the solids-not-fat alone—unless this is well below 8.0%. A determination of the milk sugar, total nitrogen and ash should be made in addition; a judgment formed on these three determinations will in all probability be correct, and if the figures for at least two of them are above the limit, the milk is probably genuine."

Richmond's table shows that the ash in abnormal milks never falls below 0.70%, and that this may be taken as the lower limit. The proteins also remain practically constant at 3.4% irrespective of the amount of solids-not-fat, whilst the lactose varies from 4.9—4.0%.

### *Calculation of added water and fat abstracted.*

When the solids-not-fat are less than 8.5%, the deficiency is found by subtracting the amount of solids-not-fat from 8.5, multiplying by 100 and dividing by 8.5.

Where the various constituents are in the ratio given by normal milk, the % deficiency of solids-not-fat may be taken as added water.

When the % fat is less than 3.0 it may be presumed that the milk has been adulterated by the abstraction of fat, or by the addition of separated milk. The % deficiency of fat is calculated by subtracting the % fat found from 3.0, multiplying by 100 and dividing by 3.

### **Routine Examination of Milk.**

For the routine examination of milk, it is usually only necessary to determine the specific gravity and the fat by the Gerber or Babcock method, the solids-not-fat being found by calculation. In case the Gerber or Babcock method is not used, the total solids may be estimated and the specific gravity observed.

For the determination of total solids, flat porcelain dishes, seven centimetres in diameter, may be used. These will keep their weight practically unchanged for a considerable time. The milk is delivered from the pipette described under the determination of the fat by the Adam's method. Neither the dish nor the milk need be weighed, as the weight of the former will be known and that of the latter will be approximately five grams. The milk is dried as usual and weighed, when the weight of solids, multiplied by twenty, will give the percentage of Total Solids.

Boric acid and formaldehyde should be tested for. If the Gerber or Babcock process is used, the detection of the latter should be carried out at the same time as previously indicated.

### **Examination and Analysis of Sterilized Milk.**

This may be examined in the same manner as ordinary milk, the only points of difference being: (a) the milk sugar, protein, ash ratio is not applicable, as the bulk of the albumin is removed during the treatment, thereby reducing the protein content by 0.3—0.4%, and (b) the milk is usually "homogenized" before sterilization, i.e., the milk is forced through fine holes under pressure, which breaks up the fat globules, reducing them to a very small size, and under these conditions they no longer coalesce and the cream does not rise. Which-ever method is used for estimation of fat, the extraction must be much more thorough than is necessary for ordinary milk.

## Examination and Analysis of Condensed Milk.

Condensed milk is manufactured by concentrating milk under reduced pressure with or without the addition of cane sugar and packing the product in sealed tins. The various brands used at the present time are as follows:—

|  | Fat.    | Solids-not-fat. | Sucrose. |
|--|---------|-----------------|----------|
| Evaporated milk - - - -                  | 7—8%    | 16—17%          | —        |
| Unsweetened condensed milk               | 9—12%   | 23—25%          | —        |
| Sweetened full-cream milk -              | 9—10·5% | 23·5—27%        | 38—42%   |
| Sweetened machine-skimmed milk - - - - - | 0·5—1%  | 25—29%          | 44—47%   |

For analysis about 30 grm. of the milk is diluted with water, boiled, cooled, made up to 100 cc., then treated as an ordinary milk. In the case of sweetened milk which has crystallised, the contents of the tin should be dissolved in a suitable amount of water, taking care that all the milk sugar redissolves.

**Total solids.** In the case of unsweetened milk the estimation is carried out on the dilute solution, as in the case of milk. If the sample is sweetened, the most satisfactory method is to weigh a dish containing about 20 grm. of clean, dry white sand, and pipette 5 cc. of the solution on it, distributing evenly over the sand, and dry to constant weight. Alternatively, 2·5 cc. of the solution may be weighed into a deep metal dish, diluted with 50 cc. of water and evaporated slowly to dryness on the water-bath, and finally dried to constant weight in the water-oven.

**Fat.** The Röse-Gottlieb method is the only completely satisfactory one. The Adams' method gives too low or too high a result according to whether the ether is anhydrous or contains a small amount of water.

**Determination of proteins and ash.**

These may be determined by the processes as given under "Milk."

**Sugars.** A method for the polarimetric determination of lactose and sucrose is described by Harrison (*Analyst*, 1904, **29**, 248; cf. Revis and Payne, *Ibid.*, 1914, **39**, 476).

Milk sugar may be estimated by the Fehling process, as given under "Milk," and cane sugar calculated by difference, or the following method may be used: 10 cc. of the milk solution are placed in a 100 cc. flask, diluted to about 50 cc., and neutralised with N/10 NaOH. Copper sulphate solution (Fehling solution A) is added drop by drop until the flocculent precipitate settles to leave a clear solution. The volume is made up to 100·67 cc. and the liquid is mixed and filtered (a).

25 cc. of the filtrate are placed in a flask, 25 cc. of water and 5 cc. of concentrated hydrochloric acid added, and the

flask is placed in a water-bath at 70°C. for 10 mins., cooled and the solution filtered and made up to 100 cc. (b).

Lactose is determined in filtrate (a) by the gravimetric Fehling method, and total sugar in solution (b). If the CuO due to lactose be subtracted from the total CuO from solution (b), the cane sugar may be calculated from the difference.

The Public Health (Condensed Milk) Regulations, 1923, require all condensed milk to be labelled in a manner which is set out in the schedule of the regulations. They also require that all condensed milk shall contain not less than an appropriate percentage of milk fat and milk solids as specified in the following table:—

| Description of Condensed Milk. | Percentage of milk and fat. | Percentage of all milk solids, including fat. |
|--------------------------------|-----------------------------|---|
| 1. Full cream, unsweetened ... | 9·0                         | 31·0  |
| 2. Full cream, sweetened ...   | 9·0                         | 31·0  |
| 3. Skimmed, unsweetened ...    | —                           | 20·0  |
| 4. Skimmed, sweetened ...      | —                           | 26·0  |

## Examination and Analysis of Dried Milk.

Dried milk is manufactured as full-cream milk, half-cream milk and machine-skimmed milk. In any case a 12—14% solution should be made and treated as ordinary milk. In case the milk does not completely dissolve in water, the powder may be directly worked on 0·5—1 gm. diluted to 5 cc. with water for the Röse-Gottlieb method; 2 gm. for moisture and ash; 2 gm. for proteins; and 1 gm. extracted with boiling water and made up to 100 cc. for sugar.

## Examination and Analysis of Cream.

*Determination of total solids and ash.*

For total solids about 2 gm. are used, proceeding as under "Milk."

For ash, at least 5 gm. should be used.

*Determination of fat.*

*The Röse-Gottlieb method.* 1 gm. is weighed into the tube, and diluted with water to 5 cc., proceeding as under "Milk."

*The Gerber method.* 10 cc. of water, 10 cc. of Gerber sulphuric acid and 1 cc. of amyl alcohol are placed in one of the special Gerber cream tubes. 5 gm. of cream are weighed out into the small tube attached to the stopper, and the whole added to the tube by quickly inserting and adjusting the stopper. The whole is well shaken, the small stopper being loosened. It is heated up to 70°C. in a bath, whirled for about 3 mins. in the centrifuge, again heated to 70°C., and the percentage of fat read off on the tube.



In calibrating the Gerber tubes it should be noted that 60% of fat in the tube occupies 3.34 cc.

#### *Preservatives.*

Boric acid is tested for, as under "Milk." The amount of boric acid may be determined by weighing out about 20 grm., and proceeding as under "Milk."

Benzoic acid may be tested for, and if necessary determined by the methods given under milk.

Formaldehyde may be detected and determined as given under "Milk," after diluting with milk of known purity.

*Detection of thickening agents.* Starch may be detected by means of iodine.

Gelatin may be detected by means of Stokes' reagent (prepared by dissolving mercury in twice its weight of nitric acid of Sp. Gr. 1.42, and diluting with water to 25 times its volume) in the following manner: 10 cc. of the cream, 20 cc. of water and 20 cc. of the reagent are mixed together, shaken vigorously, allowed to stand for 5 mins. and filtered; in presence of much gelatin, it will be impossible to obtain a clear filtrate, whilst the addition of an equal volume of a saturated aqueous picric acid solution to the filtrate will produce immediately a yellow precipitate.

Calcium saccharate ("Viscogen") may be detected by estimating the percentage of lime in the ash, which on the average is 22.4% (*Analyst*, 1908, **33**, 401).

Cane sugar may be detected as follows: 15 cc. of milk or cream are mixed with 1 grm. of resorcinol and 1 cc. of strong hydrochloric acid, and the mixture raised to the boil. Cane sugar produces a red colour; a milk of known purity should be similarly treated for comparison. (Cf. *Analyst*, 1918, **43**, 292.)

#### *Legal requirements.*

According to the Milk and Cream Regulations of 1912 and the amendment of 1917, no addition of any kind must be made to cream containing less than 35% of fat. The only permissible preservatives which may be added to cream containing more than 35% of fat are boric acid, borax, or hydrogen peroxide, the percentage of the two former being not greater than 0.4%, calculated as boric acid, providing that a label of stated dimensions is attached to the receptacle containing the preserved cream.

### **Examination and Analysis of Butter.**

In the ordinary examination of butter, the two chief points are the nature of the fat and the amount of water present. Other determinations often required are the amount of milk solids, of salt and of preservatives.

*Determination of water, casein and salt.* 2 grm. are

heated in a flat-bottomed dish for 2 hrs. on the water-bath or 10 grm. are heated in a basin over a small flame (with care to prevent burning) until all evolution of bubbles has ceased. Casein and salt may be determined by washing the residue with ether until free from fat, drying and weighing; the casein settles very rapidly, and the ether can be decanted without loss. Salt is determined by dissolving the residue in water and titrating with N/10 silver nitrate, or by taking the ash of the butter (obtained at a low temperature) as salt.

Dried milk is occasionally added to butter, and may be detected by determination of the milk sugar, which does not exceed 0.4% in a normal butter.

The percentage of fat may be determined by evaporating the ether and weighing the fat, but it is usually quite satisfactory to determine fat by difference.

Water may be determined in routine work by means of the Stokes' tube (*Richmond*, 3rd edition, p. 240). This tube is a cylindrical one open at both ends, the upper half having a diameter of 28 mm., and the lower half having a diameter of 9 mm. The lower half is closed by a rubber bung, and is calibrated into divisions each one representing 1% of water in the butter. The tube, with the bung in position, is immersed in hot water, and butter is added up to a 15 cc. mark on the upper half. The tube is then transferred to a centrifuge and is whirled until all the water has collected in the narrow end of the tube. The approximate percentage of water can then be read off directly. The clarified butter fat which is perfectly clear and practically dry may be removed and used for the other determinations.

According to the Sale of Butter Regulations, 1902, "where the proportion of water in a sample of butter exceeds 16%, it shall be presumed for the purposes of the Sale of Food and Drugs Act, 1875—1899, until the contrary is proved, that the butter is not genuine by reason of the excessive amount of water therein."

*Examination of fat.* About 20 grm. of butter are melted in a small beaker on the water-bath. The appearance of the melted fat should be carefully noticed. In the case of a pure untreated butter the water and curd will sink to the bottom, and the fat will be quite clear. In the case of margarine, the fat will always be turbid, although turbid fat does not necessarily imply adulteration, some reworked butters often showing a certain amount of turbidity. The fat is filtered through a thick filter paper into another beaker, and is then used for further examination.

The chief method of examination is the Leffmann-Beam modification of the Reichert-Wollny process with the later modification of Polenske and Kirschner.



*Reichert-Polenske process.* 5 grm. of the fat are weighed out into a 300 cc. flat-bottomed flask, 20 grm. of glycerol and 2 cc. of 50% caustic soda solution are added, and the flask is heated until the contents are clear. (In case a number of samples have to be examined, it is convenient to prepare a quantity of glycerol containing the requisite amount of soda and to measure out about 20 cc. of this "glycerol soda" for each experiment.) 100 cc. of boiled distilled water are added, and the soap is dissolved. 0.1 grm. of pumice, which has been ground and sifted through muslin, is added, and 40 cc. of sulphuric acid (of such concentration that 35 cc. neutralise 2 cc. of the caustic soda solution) are added. The flask is then connected with the distilling apparatus, which is of standard proportions (*Analyst*, 1904, **29**, 154). This apparatus, is somewhat similar to the Reichert-Wollny apparatus, but the condenser is upright. The flask is heated gently until the acids melt, and then the flame is adjusted so that 110 cc. distil in 19 to 21 mins. The flask containing the distillate is removed and replaced by a 25 cc. cylinder to catch any drops. The contents of the 110 cc. flask are mixed and cooled. The distillate is then filtered, and 100 cc. are titrated with N/10 soda. The number of cc.'s of N/10 soda used (less that used in the blank experiment), multiplied by 1.1 (to correct for the 110 cc.'s distilled), gives the Reichert-Wollny number. The condenser tube, flask and cylinder are washed with 18 cc. of water, and the washings poured through the filter; the condenser, flask, and cylinder are then washed with 20, 15, and 10 cc. of alcohol respectively, pouring the washings through the filter. The mixed alcoholic solutions are then titrated with N/10 caustic soda, using phenolphthalein as indicator, and a blank experiment is also carried out. The number of cc. of N/10 caustic soda less the blank is the Polenske value.

The Polenske number generally varies with the Reichert-Wollny number. For butters with a Reichert-Wollny number of 20, the Polenske number is about 1.3; when the Reichert-Wollny number is 25, the Polenske number is about 1.8; and when the Reichert-Wollny number is 30, the Polenske number increases to 2.5 to 3.0.

The Butter Regulations Committee recommended that a Reichert-Wollny number of 24 be taken as the limit for butter, and a Reichert-Wollny number of 4 as representing 10% of butter fat when margarine is under examination. The presence of coconut oil, however, which has come largely into use since this recommendation was made, renders these figures useless unless the absence of coconut oil or similar products is proved. An average Reichert-Wollny number for genuine butter is about 28 to 32. A lower Reichert-Wollny

number value than 24, together with a low Polenske number, would suggest the presence of oleo-margarine (Reichert number about 1), whilst a higher Polenske number than that corresponding to the Reichert number would indicate the presence of coconut oil or other similar substance.

*Kirschner process.* 0.5 gm. of finely-powdered silver sulphate is added to the 100 cc. of the neutralised distillate of volatile fatty acids obtained in the Polenske process, and after standing for an hour with occasional shaking the liquid is filtered. 100 cc. of the filtrate are placed in the distilling flask, 35 cc. of water, which has been well boiled, and 10 cc. of the sulphuric acid solution previously used, added; a small amount of pumice is placed in the flask, and 110 cc. distilled as in the Polenske process; 100 cc. of the distillate are titrated with N/10 caustic soda, and after correction for the figure obtained in a blank experiment, the Kirschner number is calculated by multiplying the number of cc. of N/10 alkali by 1.21 and by  $(100 + X) \div 100$  ( $X$  = cc. of alkali added to the Reichert distillate for neutralisation). The Kirschner process is of special value for estimation of the quantity of butter in mixtures containing small amounts when large quantities of other fats are present, e.g., in margarine, which under the Margarine Act is not permitted to contain more than 10% of butter.

*Calculation of the percentage of Butter, Coconut Oil and Oleo-margarine in Mixtures.*

The following method of calculation has been worked out by Cribb and Richards (*Analyst*, 1911, **36**, 327) and by Arnaud and Hawley (*Analyst*, 1912, **37**, 122):—

R = Reichert number, P = Polenske number, K = Kirschner number.

The figures for oleo-margarine may be taken as R = 0.3, P = 0.4, K = 0.3.

T = Transfer number which is 1.9, unless P is less than 2.5, in which case T is found from the curve given by Arnaud and Hawley

Polenske number due to coconut oil =  $P - 0.4 + T - R/10$ .

$$\% \text{ Coconut oil in sample} = \frac{\text{Polenske no. due to coconut oil}}{0.176}$$

(P for coconut oil = 17.6).

Reichert number due to butter

$$= R - 0.3 - T - (0.065 \times \text{percentage of coconut oil}).$$

$$\% \text{ Butter fat} = \frac{\text{Reichert due to butter}}{0.29} \quad \left( \text{this assumes R for butter} = 29.0 \right)$$

(N.B.—The factor  $0.065 \times \% \text{ coconut oil}$  gives the Reichert due to coconut oil and assumes that for coconut oil R = 6.5.)

To calculate from Kirschner (K).

Kirschner number due to butter.

$$= K - 0.3 - P/10.$$

$$\% \text{ Butter} = \frac{\text{Kirschner no. due to butter}}{0.23} \quad (\text{K for butter} = 23).$$

This is the most reliable method of estimating up to 25% of butter in margarine.

$$\text{Oleo-margarine} = 100 - \% \text{ coconut oil} - \% \text{ butter.}$$

The above method of calculation assumes that the oil present having a high Polenske number is coconut oil. Recently large quantities of palm kernel oil have been used in the manufacture of margarine, the presence of which considerably complicates the calculation. Methods for distinguishing between these two oils have been proposed by Burnett and Reyis (*Analyst*, 1913, **38**, 255), and by Elsdon, (*Analyst*, 1917, **42**, 72, 295, 298).

An alternative method for the determination of coconut oil and similar products in mixtures has been suggested by Shrewsbury and Knapp (*Analyst*, 1910, **35**, 385). For this method and for various comments and modifications the original paper should be consulted together with the following references: *Analyst*, 1911, **36**, 195, 327, 344; 1912, **37**, 3; 1917, **42**, 72. This method has been combined with the Reichert-Polenske process by Elsdon (*Ibid.*, 1917, **42**, 295).

A process somewhat similar to that of Polenske has been proposed by Blichfeldt (*J.S.C.I.*, 1910, **29**, 792; 1919, **38**, 1501), which is largely used by margarine manufacturers in England. A modification of this is due to Gilmour (*Analyst*, 1920, **45**, 2), but neither process would seem to have any particular advantage over that of Polenske.

#### *Refractometer.*

A rapid method of examination is by means of the refractive index. This may be found either by means of the Abbé refractometer or the Zeiss butyro-refractometer. The former reads directly in refractive indices; the latter on an arbitrary scale, divided into a hundred parts. Pure butter has a refractive index of about 1.454, oleo-margarine 1.459, whilst coconut oil is usually less than 1.450. A suitable mixture of coconut oil and oleo-margarine will therefore have the same refractive index as pure butter.

#### *Preservatives.*

The Departmental Committee on the Use of Preservatives in Food recommended that the only preservative permitted to be used in butter and margarine be boric acid, or mixtures

of boric acid and borax, in proportions not exceeding 0.5% calculated as boric acid.

*Detection of boric acid.* A few drops of the water which has settled from the melted butter are placed in one of the depressions of a spot-plate. 1 drop of tincture of turmeric, and one drop of hydrochloric acid (for concentrations see under "Milk") are added; on drying on the water-bath, a red coloration will be produced in the presence of boric acid.

*Determination of boric acid.* 6.2 grm. of butter are weighed out into a 250 cc. wide-mouthed flask. About 50 cc. of water are added and a few drops of litmus solution. The whole is then made acid with a few drops of N/10 hydrochloric acid, and boiled for a few minutes to eliminate carbon dioxide. The solution is cooled, neutralised to litmus with N/10 caustic soda, about 20 cc. of glycerol or 10 grm. mannitol added and the titration continued until neutral to phenolphthalein. Each cc. of soda used (allowing for any acidity due to the glycerol) after the addition of the glycerol, is equivalent to 0.1% of boric acid in the butter. In an alternative method two or three times the amount of butter may be melted in a separator, washed out several times with hot water, the washings mixed, made up to a known volume and an aliquot portion evaporated to dryness with a slight excess of caustic soda and ignited; the boric acid in the residue is then determined as before.

*Other preservatives* occasionally found in butter are salicylic acid and fluorides. Salicylic acid may be detected as under "Milk." Fluorides may be detected in the following manner: "10 grm. of the sample are melted and shaken up in a separator and heated with 1—2 cc. of water. The aqueous layer is run off into a test-tube, a few drops of hydrogen peroxide and 1 cc. of a solution containing about 2% titanium sulphate in 10% sulphuric acid added. A blank test is made in exactly the same way on 10 grm. of pure butter. If the original sample contains fluoride, the orange yellow colour of the peroxidised titanium solution will be partially discharged, and on comparison with the colour obtained in the blank test on pure butter the difference is seen to be very marked." (L.G.B. Food Reports, No. 17).

#### *Routine Examination.*

15 cc. of the sample are placed in one of the Stokes' butter tubes already mentioned. The tube is heated to 70° in the water-bath, whirled for 3 mins. in a centrifuge, and the amount of water is noted. The fat, which is sufficiently clear for subsequent examinations, is then decanted, and the tube filled up to the mark with approximately N/5 hydrochloric acid. The curd is broken down by means of a glass rod, and the

liquid thoroughly mixed. 10 cc. of this liquid are removed by means of a pipette to a 50 cc. beaker and mixed with 5 cc. of turmeric tincture (prepared by warming 5 grm. of powdered turmeric and 5 grm. of crystallised tartaric acid with 500 cc of industrial methylated spirit for 4 hrs. and filtering), allowed to stand for 1 hr. and compared with a similar solution prepared with a butter known to be free from boric acid. If the yellow colour produced by the sample is deeper than that produced by the butter of known purity, standards should be prepared representing 0.5%, 0.3% and 0.1% boric acid by taking 5 cc., 3 cc. and 1 cc. of a standard boric acid solution (prepared by dissolving 1% of boric acid in approximately N/5 hydrochloric acid), making up to 9.5 cc. with N/10 hydrochloric acid, and adding 0.5 cc. of milk; the colours are compared at the end of 1 hr. (Hawley, *Analyst*, 1915, 40, 150). The separated fat may be examined by the Reichert process.

## Examination and Analysis of Cheese.

*Determination of water and ash.* This may be carried out by drying 5 grm. of the sample, cut into very thin slices, at 105°C. until constant in weight; the addition of a small amount of absolute alcohol will assist the drying. The ash may be determined on the same portion, heating gently to not more than a dull red in the dark. Gorgonzola cheese is frequently coated with a fairly thick layer of a mixture of tallow and barytes. The amount of coating in extreme cases being as much as one-third of the weight of the whole cheese.

*Determination of chlorides.* 1 grm. of cheese is placed in a Kjeldahl flask with 20 cc. of strong sulphuric acid. A nitrogen bulb containing a known volume of N/10 silver nitrate and some strong nitric acid is inserted into the neck of the flask by means of a tightly-fitting cork. The flask is clamped in an almost horizontal position and heated. When the reaction is complete the residual silver nitrate is determined, and from this the amount of chloride calculated.

*Determination of proteins.* This is carried out by the Kjeldahl process, using about 1.5–2 grm. of cheese. The percentage of nitrogen multiplied by 6.38 is equal to the percentage of proteins.

*Determination of Fat.*

Gerber method. This is carried out exactly as described under "Cream," with the exception that the 5 grm. of cheese are added directly to the Gerber tube and not weighed out in the small tube. In the case of certain cheeses a considerable time is required for complete disintegration.



**Extraction method.** 1—2 grm. are ground up to a fine powder with at least an equal quantity of sand, and the mixture transferred to a stoppered cylinder and extracted several times with ether. The ethereal solution is evaporated and the fat dried and weighed. The Röse-Gottlieb method may also be used with advantage.

**Examination of fat.** A quantity of cheese is cut up into fairly small pieces and placed on a porcelain filter plate resting in a funnel, and allowed to remain in the water-oven until the fat has run off. If sufficient fat cannot be obtained by this method, extraction with ether and evaporation must be resorted to. The fat so obtained is examined by the methods given under "Butter-fat."

The composition of various kinds of cheese is treated by the following among others: Camembert cheese (Buttenburg and Guth. *Analyst*, 1908, **33**, 5); cream cheese (Cribb. *Ibid.*, 1909, **34**, 45); Dutch cheese (Cribb. *Ibid.*, 1906, **31**, 105; Van Rijn. *Ibid.*, 1915, **40**, 391); Roquefort cheese (Dox. *Ibid.*, 1911, **36**, 542).

---

## STANDARD UNITED STATES METHODS.

In case the Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists differ from the standard English methods, a summary of the differences is given below.

### Examination and Analysis of Milk.

#### Determination of fat.

##### *Röse-Gottlieb method.*

10—11 grm. of the milk is thoroughly mixed with 1.25 cc. of concentrated ammonium hydroxide (2 cc. if the sample is sour) in a Rohrig tube or similar apparatus, and then with 10 cc. of alcohol (95% by vol.). The mixture is shaken for 30 secs. with 25 cc. of washed ether, then shaken again for 30 secs. after addition of 25 cc. of petroleum ether (B.Pt. below 60°C.). After allowing to stand for 20 mins., the ethereal solution of fat is drawn off as completely as possible, and filtered into a tared flask. The liquid remaining in the tube is re-extracted with 15 cc. of each ether, shaken for 30 secs., and the clear solution drawn off and filtered, through the same filter, into the same tared flask. The tip of the spigot of the extraction tube, the funnel and the filter, are washed with a mixture of equal parts of the two ethers, and then the united ethereal

# Analyses of Milk of Known Purity. (Lythgoe).

| Breed.              | Weight of<br>Milk (lbs.). | Sp. Gr. 15°C.<br>(Quevenne<br>Scale). | Total<br>Solids. | Fat. | Lactose. | Protein. | Ash. | Solids-not-<br>fat. |
|---------------------|---------------------------|---------------------------------------|------------------|------|----------|----------|------|---------------------|
| Grade Durham ....   | 15                        | 35                                    | 14.58            | 5.10 | 5.00     | 3.35     | 0.81 | 9.48                |
| Holstein .....      | 15                        | 34                                    | 13.65            | 4.50 | 4.95     | 3.33     | 0.72 | 9.15                |
| Grade .....         | 20                        | 33                                    | 13.36            | 4.30 | 5.00     | 3.25     | 0.81 | 9.06                |
| Grade Ayrshire ..   | 12                        | 33                                    | 13.26            | 4.20 | 5.50     | 2.84     | 0.66 | 9.06                |
| Grade Swiss .....   | 16                        | 33                                    | 13.20            | 4.35 | 4.75     | 3.29     | 0.76 | 8.85                |
| Grade Durham ....   | 15                        | 33                                    | 13.06            | 3.80 | 5.75     | 3.37     | 0.69 | 9.26                |
| Ayrshire .....      | 10                        | 31                                    | 12.91            | 3.90 | 4.35     | 3.51     | 0.76 | 9.01                |
| Grade Holstein .... | 17                        | 32                                    | 12.78            | 4.00 | 5.05     | 2.89     | 0.71 | 8.78                |
| Holstein .....      | 10                        | 31                                    | 12.66            | 3.90 | 4.35     | 2.97     | 0.76 | 8.76                |
| Grade Durham ....   | 18                        | 34                                    | 12.54            | 3.50 | 5.25     | 2.97     | 0.68 | 9.04                |
| Grade Ayrshire ..   | 16                        | 32                                    | 12.08            | 3.70 | 4.65     | 2.80     | 0.78 | 8.38                |
| Grade Holstein .... | 20                        | 34                                    | 12.00            | 3.10 | 5.05     | 2.99     | 0.71 | 8.90                |
| Holstein .....      | 16                        | 33                                    | 11.40            | 3.20 | 5.00     | 2.48     | 0.72 | 8.20                |
| Holstein .....      | 28                        | 30                                    | 10.20            | 2.65 | 4.50     | 2.40     | 0.65 | 7.55                |

*Quevenne Lactometer Degrees.* The lactometer reading is expressed in whole numbers for convenience; the true Sp. Gr. is obtained by writing 1.0 before the lactometer reading.  
To convert Quevenne degrees to New York Board of Health degrees, they must be divided by 0.29.



filtrates and washings are evaporated slowly and dried in a boiling water-oven to constant weight. For accurate results, a third extraction is advisable. The fat is re-dissolved in petroleum ether, and if any residue remains, it is filtered off, dried, and the weight deducted from the original weight.

#### *Babcock method.*

This test is performed in special Babcock bottles, with long, narrow, graduated necks; the graduations, in the case of milk bottles cover 8%, divided in 1/10ths%, and in the case of cream bottles cover 50%, graduated in halves of 1%. 17.6 cc. of the milk are run from a pipette (graduated to deliver 17.6 cc. of water at 20°C. in 5 to 8 secs.) into the bottle, together with 17.5 cc. sulphuric acid (Sp. Gr. 1.82—1.83). The milk and acid are well mixed, and when the curd is dissolved, are centrifuged for 4 mins. at the required speed for the centrifuge employed. Boiling water is added to bring the fat within the scale on the neck of the bottle, and after a further centrifuging of 1 min., the percentage of fat is read directly from the length of the column of fat, readings being made at 57—60°C., at which temperature the fat is wholly liquid.

For details of the manipulation of the Babcock test, and its application in the analysis of dairy products other than milk, see Farrington and Woll, "Testing Milk and Its Products," and Van Slyke, "Modern Methods of Testing Milk."

#### *Calculation of added water and fat abstracted.*

This calculation is made as under English methods for milk, except that the particular State and municipal standard should be substituted if it differs from 8.5% of solids-not-fat and 3.0% of fat.

#### **Adulteration of milk.**

Until recently the standard for milk was not less than 8.5% of solids-not-fat, and not less than 3.25% of fat, but this national standard is not now in force, and adulteration is controlled by the State and Municipal standards which range from 11 to 13% as minimum limits for total solids, and from 2.5 to 3.7% as minimum limits for fat.

## **Examination and Analysis of Cream.**

#### *Determination of fat.*

*The Babcock method.* 9 or 18 grm. of cream is weighed into a tared Babcock bottle, and made up to 18 grm. with water if necessary. 17.5 cc. of sulphuric acid is added, and the process continued as under "Milk" (see above).

## Examination and Analysis of Butter.

*U.S. standard butter* is butter containing not less than 82.5% of butter fat. By Acts of Congress, approved August 2 1886 and May 9 1902, butter may also contain added colouring matter, but the colour added must conform to the general regulations governing use of colouring in food products.

### *Preservatives.*

Formerly "boric mixture" (borax and boric acid) was used in the United States, and its use is still permitted in England. Now, only sodium benzoate may be used in the United States, and that must be declared. Dairymen seldom use it in butter for domestic use, but some brands of nut butter contain it. Formaldehyde, salicylic acid and sulphurous acid are more infrequently used in butter as preservatives.

### *Detection and determination of benzoic acid.*

The aqueous portion is separated from 10 grm. of butter, and the fat shaken several times with hot sodium bicarbonate solution. The mixed washings and aqueous portion are heated with an equal volume of concentrated hydrochloric acid, and the method continued as under milk (see earlier).

An alternative method of detection (official method of the A.O.A.C.) is the *Halphen-Robin method*. 25 grm. of the melted sample is agitated with a solution of 0.4—0.5 grm. of sodium bicarbonate in 50 cc. of water and 15 cc. of 95% alcohol in a separating funnel. After allowing to stand 6 mins., the alkaline liquor is drawn off into a flask, and acidified with concentrated sulphuric or hydrochloric acid. The contents of the flask are then heated almost to the boil, shaken with a small amount of talc or infusorial earth, and filtered, returning the first portions through the filter until the filtrate runs perfectly clear. The filtrate is cooled, extracted with 40 cc. of ether, the ether extract washed with a mixture of 20 cc. of water and 5 cc. of 95% alcohol, and tested by the *Mohler method* as follows:

The ether extract is evaporated to dryness, the residue dissolved up in 1 to 3 cc. of N/3 sodium hydroxide, and again evaporated to dryness. To the residue are added 5—10 drops of concentrated sulphuric acid and a crystal of potassium nitrate. The mixture is heated for 20 mins. in a boiling water bath, forming meta-di-nitro benzoic acid. After cooling, the mixture is diluted with 1 cc. of water, made distinctly ammoniacal, and boiled to decompose any ammonium nitrite formed. The solution is cooled and a few drops of colourless ammonium sulphide solution run down the side of the tube.

A red-brown ring (ammonium meta-di-amido benzoic acid) at the junction of the two layers indicates the presence of benzoic acid. On mixing and heating, the colour changes to greenish-yellow (distinction from salicylic and cinnamic acids). The presence of phenolphthalein interferes with the test.

## Examination and Analysis of Cheese.

*Determination of acidity.* Water at 40°C. is added to 10 gm. of the finely divided cheese until the total volume is 105 cc. The mixture is shaken thoroughly, filtered, and 25 cc. of the filtrate (representing 2.5 gm. of the sample) is titrated with N/10 sodium hydroxide. The result is expressed as percentage of lactic acid.

*U.S. standard cheese* contains at least 50% of fat.

## Examination and Analysis of Ice Cream.

The sample is allowed to soften at room temperature, and thoroughly mixed by means of a spoon or egg-beater, or by pouring back and forth between beakers.

*Determination of fat.* 4 gm. of the sample is thoroughly mixed with 3 cc. of water in a small dry beaker, transferred to a Rohrig tube, washing out the beaker with an additional 3 cc. of water. 2 cc. of concentrated ammonium hydroxide are added, and the whole well mixed and heated in a water-bath at 60°C. From this point the procedure is as under the Röse-Gottlieb method (See "Milk Analysis.").

The *U.S. standard* for ice cream is not less than 14% of milk fat, except when mixed with fruit or nuts, when the standard is 12%.

*Detection of thickening ingredients.* See under "cream."

## Artificial Colouring Matters in Dairy and other Food Products.

The laws of the United States (more particularly the Food and Drugs Act, 1906) do not prohibit the addition of artificial colouring substances to food, unless (a) the colouring matter added is poisonous, or otherwise objectionable, and (b) the colouring matters serve to conceal damage or inferiority). However, in most States the laws have the practical effect of excluding artificial colouring from most food products on one or other of the above grounds. The detection and identification of artificial colours is a complicated procedure, for complete instructions regarding which see (a) "Methods of

Analysis: Association of Official Agricultural Chemists," Washington, D.C., and (b) "Food Inspection and Analysis," by A. E. Leech, 4th ed.

Seven coal tar dyes have been definitely approved by the U.S. Department of Agriculture, and are usually referred to as the seven certified colours.

The following quotation from "Food Inspection Decision," No. 76, July 13th, 1907, explains the conditions under which these can be used :—

"The use of any dye, harmless or otherwise, to colour or stain a food in a manner whereby damage or inferiority is concealed is specifically prohibited by law. The use in food for any purpose of any mineral dye or any coal-tar dye, except those coal-tar dyes hereinafter named, made specifically for use in foods, and which bear a guarantee from the manufacturer that they are free from subsidiary products and represent the actual substance, the name of which they bear, may be used in foods. In every case a certificate that the dye in question has been tested by competent experts and found to be free from harmful constituents must be filed with the Secretary of Agriculture and approved by him. The following coal-tar dyes which may be used in this manner are given numbers, the numbers preceding the names referring to the number of the dye in question as listed in A. G. Green's edition of the 'Schultz-Julius Systematic Survey of the Organic Colouring Matters,' published in 1904. The list is as follows :

*Red shades* : 107 Amaranth. 56 Ponceau 3 R. 517 Erythrosin.

*Orange shade* : 85 Orange I.

*Yellow shade* : 4 Naphthol yellow S.

*Green shade* : 435 Light green S. F. yellowish.

*Blue shade* : 692 Indigo disulpho acid.

Each of these colours shall be free from any colouring matter other than the one specified, and shall not contain any contamination due to imperfect or incomplete manufacture."

---

# CARBOHYDRATES.

F. ROBINSON, M.Sc. Tech., B.Sc., F.I.C.

## BEHAVIOUR OF SUGARS TOWARDS CERTAIN REAGENTS.

| Sugar.       | Fehling's solution. | Knapp's solution. | Sachsse's solution. | Barfoed's solution. | Nylander's solution. |
|--------------|---------------------|-------------------|---------------------|---------------------|----------------------|
| Dextrose     | ppt.                | ppt.              | ppt.                | ppt.                | ppt.                 |
| Lævulose     | ppt.                | ppt.              | ppt.                | ppt.                | ppt.                 |
| Invert sugar | ppt.                | ppt.              | ppt.                | ppt.                | ppt.                 |
| Galactose    | ppt.                | ppt.              | ppt.                | ppt.                | ppt.                 |
| Lactose      | ppt.                | ppt.              | ppt.                | -                   | -                    |
| Maltose      | ppt.                | ppt.              | ppt.                | -                   | -                    |
| Sucrose      | -                   | -                 | -                   | -                   | -                    |

The above tests are to be carried out at the boil.

Fehling's solution.

(A) Copper solution.

69.2 gram. recrystallised  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ , made up to 1000 cc.

(B) Alkaline tartrate solution.

346 gram. Rochelle salt and 130 gram. caustic soda made up to 1000 cc.

The two solutions are to be kept separate, and equal volumes mixed as required, from which mixture the volumes required are measured.

*As Fehling's solution usually gives a few mgm.  $\text{Cu}_2\text{O}$  when heated to  $100^\circ\text{C}$ ., a blank to determine this amount should be made with each fresh solution and the necessary correction made in all sugar estimations.*

Knapp's solution. 10 gram. mercuric cyanide in 100 cc. NaOH solution (1.145 Sp. Gr.), made up to 1000 cc.

Sachsse's solution. 18 gram. mercuric iodide, 25 gram. potassium iodide, and 80 gram. KOH in 1000 cc.

Barfoed's solution. 66 gram. cupric acetate and 10 cc. glacial acetic acid are dissolved in water and diluted to 1000 cc.

Nylander's solution. 40 gram. Rochelle salt and 20 gram. bismuth subnitrate dissolved in 1000 cc. of 8 per cent. caustic soda solution.

### 1. Cane Sugar.

### I. Determination of Invert Sugar in Commercial Cane Sugars.

In case the invert sugar is under 3 per cent., Method A may be used; for all cases in which the invert sugar is over 2.5 per cent., Method B may be used.

### Method A.

Per cent. Invert.

Herzfeld's method determines between 0.05 and 1.50

Baumann's " " " " 0.04 and 3.21

3.33 gm. of a sample containing more than 1.5 per cent. invert sugar completely reduces 10 cc. Fehling's solution, and Baumann's method must then be used.

*Herzfeld's method.* For fairly pure products 20 grm. are dissolved up to 100 cc. and 50 cc of the filtrate taken.

In other cases 25 grm. are dissolved up to 100 cc. after adding basic lead acetate; 60 cc. of the filtrate are treated with sodium carbonate solution to remove lead, made up to 75 cc., and 50 cc. of the filtrate taken (= 10 grm. original substance).

The 50 cc. filtrate is mixed with 50 cc. Fehling's solution in an Erlenmeyer flask, and raised to the boil in 3-4 minutes over a wire gauze circle in an asbestos board, and boiled for exactly 2 minutes; 100 cc. of water are added and the liquid filtered through asbestos in a tared Gooch crucible. The asbestos used in preparing the filter must be boiled previously with caustic soda solution. The filter is not allowed to run dry, and the precipitated  $\text{Cu}_2\text{O}$  is washed on with cold water; finally, the filter is washed with hot water, alcohol, and ether, dried, ignited inside another crucible to  $\text{CuO}$ , and weighed. It is preferable to weigh as  $\text{CuO}$ , since any impurities carried down with the  $\text{Cu}_2\text{O}$  are thereby burnt away.

$$\text{CuO} \times 0.79892 \text{ (Log.} = 1.90205) = \text{Cu}$$



## PER CENT. INVERT SUGAR IN CANE SUGARS (Herzfeld).

| Cu. Invert<br>mgm. per cent. | Cu. Invert<br>mgm. per cent. | Cu. Invert<br>mgm. per cent. | Cu. Invert<br>mgm. per cent. |
|------------------------------|------------------------------|------------------------------|------------------------------|
| 50                           | 0.05                         | 120                          | 0.40                         |
| 55                           | 0.07                         | 125                          | 0.43                         |
| 60                           | 0.09                         | 130                          | 0.45                         |
| 65                           | 0.11                         | 135                          | 0.48                         |
| 70                           | 0.14                         | 140                          | 0.51                         |
| 75                           | 0.16                         | 145                          | 0.53                         |
| 80                           | 0.19                         | 150                          | 0.56                         |
| 85                           | 0.21                         | 155                          | 0.59                         |
| 90                           | 0.24                         | 160                          | 0.62                         |
| 95                           | 0.27                         | 165                          | 0.65                         |
| 100                          | 0.30                         | 170                          | 0.68                         |
| 105                          | 0.32                         | 175                          | 0.71                         |
| 110                          | 0.35                         | 180                          | 0.74                         |
| 115                          | 0.38                         | 185                          | 0.76                         |

*Baumann's method.* Many products, especially syrups and molasses, give green copper compounds if 10 grm. of substance is used, thereby interfering with the invert sugar estimation; therefore in such cases only 10 grm. is dissolved up to 100 cc. and 50 cc. taken and treated as in the Herzfeld method.

## PER CENT. INVERT SUGAR IN CANE SUGARS (Baumann).

| Cu. Invert<br>mgm. per cent. | Cu. Invert<br>mgm. per cent. | Cu. Invert<br>mgm. per cent. | Cu. Invert<br>mgm. per cent. |
|------------------------------|------------------------------|------------------------------|------------------------------|
| 35                           | 0.04                         | 110                          | 0.83                         |
| 40                           | 0.09                         | 115                          | 0.88                         |
| 45                           | 0.14                         | 120                          | 0.93                         |
| 50                           | 0.19                         | 125                          | 0.99                         |
| 55                           | 0.25                         | 130                          | 1.04                         |
| 60                           | 0.30                         | 135                          | 1.10                         |
| 65                           | 0.35                         | 140                          | 1.15                         |
| 70                           | 0.40                         | 145                          | 1.21                         |
| 75                           | 0.45                         | 150                          | 1.26                         |
| 80                           | 0.51                         | 155                          | 1.31                         |
| 85                           | 0.56                         | 160                          | 1.37                         |
| 90                           | 0.61                         | 165                          | 1.42                         |
| 95                           | 0.66                         | 170                          | 1.48                         |
| 100                          | 0.72                         | 175                          | 1.54                         |
| 105                          | 0.77                         | 180                          | 1.59                         |



**Method B.** H. Brown, Morris and Millar, *J.C.S.*, 1897, 71, 278.  
 The actual Cu weighed should be between 0.15 and 0.35 gm.  
 (= 0.07–0.17 gm. dextrose).

The actual CuO weighed should be between 0.188 and 0.438 gm.

With the tables given below :—

10 cc. of a 20 per cent. solution of sample will be suitable for  
 2.5–10 per cent. invert sugar on sample.

10 cc. of a 10 per cent. solution of sample will be suitable for  
 5–20 per cent. invert sugar on sample.

5 cc. of a 10 per cent. solution of sample will be suitable for  
 10–40 per cent. invert sugar on sample.

50 cc. of Fehling's solution are mixed with an amount of water such that, with the sugar solution to be added subsequently, the total volume = 100 cc. The beaker containing the mixture is covered with a watch-glass and placed in a boiling water-bath for 20 minutes, at the end of which time the sugar solution is added, and the beaker left in the boiling water-bath for exactly 12 minutes. At the end of this time the precipitate of  $\text{Cu}_2\text{O}$  is filtered through asbestos in a Gooch crucible, washed, dried, ignited by placing the Gooch crucible inside a larger ordinary crucible, and weighed.

The invert sugar is calculated from the CuO according to the following table of Brown, Morris and Millar :—

| Dextrose.         |             |              |  | Lævulose.         |             |              |  | Invert Sugar.            |             |              |  |
|-------------------|-------------|--------------|--|-------------------|-------------|--------------|--|--------------------------|-------------|--------------|--|
| Dextrose<br>gram. | Cu<br>gram. | CuO<br>gram. | Cu equivalent<br>to 1 gram.<br>Dextrose. | Lævulose<br>gram. | Cu<br>gram. | CuO<br>gram. | Cu equivalent<br>to 1 gram.<br>Lævulose. | Invert<br>sugar<br>gram. | Cu<br>gram. | CuO<br>gram. |  |
| 0.050             | 0.1030      | 0.1289       | 2.060                                    | 0.050             | 0.0923      | 0.1155       | 1.846                                    | 0.050                    | 0.0975      | 0.1221       |  |
| 0.055             | 0.1134      | 0.1422       | 2.061                                    | 0.055             | 0.1027      | 0.1287       | 1.858                                    | 0.055                    | 0.1076      | 0.1349       |  |
| 0.060             | 0.1238      | 0.1552       | 2.063                                    | 0.060             | 0.1122      | 0.1407       | 1.870                                    | 0.060                    | 0.1176      | 0.1474       |  |
| 0.065             | 0.1342      | 0.1682       | 2.062                                    | 0.065             | 0.1216      | 0.1524       | 1.871                                    | 0.065                    | 0.1275      | 0.1598       |  |
| 0.070             | 0.1443      | 0.1809       | 2.061                                    | 0.070             | 0.1312      | 0.1645       | 1.874                                    | 0.070                    | 0.1373      | 0.1721       |  |
| 0.075             | 0.1543      | 0.1935       | 2.058                                    | 0.075             | 0.1405      | 0.1761       | 1.873                                    | 0.075                    | 0.1468      | 0.1840       |  |
| 0.080             | 0.1644      | 0.2061       | 2.055                                    | 0.080             | 0.1500      | 0.1881       | 1.875                                    | 0.080                    | 0.1566      | 0.1963       |  |
| 0.085             | 0.1740      | 0.2187       | 2.046                                    | 0.085             | 0.1590      | 0.1993       | 1.871                                    | 0.085                    | 0.1662      | 0.2084       |  |
| 0.090             | 0.1834      | 0.2299       | 2.038                                    | 0.090             | 0.1686      | 0.2114       | 1.873                                    | 0.090                    | 0.1755      | 0.2200       |  |
| 0.095             | 0.1930      | 0.2420       | 2.033                                    | 0.095             | 0.1774      | 0.2224       | 1.868                                    | 0.095                    | 0.1848      | 0.2317       |  |
| 0.100             | 0.2027      | 0.2538       | 2.027                                    | 0.100             | 0.1862      | 0.2331       | 1.862                                    | 0.100                    | 0.1941      | 0.2430       |  |
| 0.105             | 0.2123      | 0.2662       | 2.024                                    | 0.105             | 0.1952      | 0.2447       | 1.859                                    | 0.105                    | 0.2034      | 0.2550       |  |
| 0.110             | 0.2218      | 0.2781       | 2.020                                    | 0.110             | 0.2040      | 0.2558       | 1.855                                    | 0.110                    | 0.2128      | 0.2668       |  |
| 0.115             | 0.2313      | 0.2900       | 2.012                                    | 0.115             | 0.2129      | 0.2669       | 1.851                                    | 0.115                    | 0.2220      | 0.2783       |  |
| 0.120             | 0.2404      | 0.3014       | 2.003                                    | 0.120             | 0.2215      | 0.2777       | 1.846                                    | 0.120                    | 0.2311      | 0.2898       |  |
| 0.125             | 0.2496      | 0.3130       | 1.997                                    | 0.125             | 0.2303      | 0.2887       | 1.843                                    | 0.125                    | 0.2400      | 0.3009       |  |
| 0.130             | 0.2585      | 0.3241       | 1.990                                    | 0.130             | 0.2390      | 0.2997       | 1.840                                    | 0.130                    | 0.2489      | 0.3121       |  |
| 0.135             | 0.2675      | 0.3354       | 1.981                                    | 0.135             | 0.2477      | 0.3106       | 1.834                                    | 0.135                    | 0.2578      | 0.3232       |  |
| 0.140             | 0.2762      | 0.3463       | 1.973                                    | 0.140             | 0.2559      | 0.3209       | 1.828                                    | 0.140                    | 0.2663      | 0.3339       |  |
| 0.145             | 0.2850      | 0.3573       | 1.964                                    | 0.145             | 0.2641      | 0.3311       | 1.822                                    | 0.145                    | 0.2750      | 0.3448       |  |
| 0.150             | 0.2934      | 0.3673       | 1.956                                    | 0.150             | 0.2723      | 0.3409       | 1.815                                    | 0.150                    | 0.2832      | 0.3546       |  |
| 0.155             | 0.3020      | 0.3787       | 1.948                                    | 0.155             | 0.2805      | 0.3517       | 1.811                                    | 0.155                    | 0.2915      | 0.3655       |  |
| 0.160             | 0.3103      | 0.3891       | 1.940                                    | 0.160             | 0.2889      | 0.3622       | 1.806                                    | 0.160                    | 0.3002      | 0.3764       |  |
| 0.165             | 0.3187      | 0.3996       | 1.931                                    | 0.165             | 0.2972      | 0.3726       | 1.803                                    | 0.165                    | 0.3086      | 0.3869       |  |
| 0.170             | 0.3268      | 0.4098       | 1.922                                    | 0.170             | 0.3053      | 0.3828       | 1.799                                    | 0.170                    | 0.3167      | 0.3971       |  |
| 0.175             | 0.3350      | 0.4200       | 1.914                                    | 0.175             | 0.3134      | 0.3930       | 1.793                                    | 0.175                    | 0.3251      | 0.4076       |  |
| 0.180             | 0.3431      | 0.4302       | 1.906                                    | 0.180             | 0.3216      | 0.4032       | 1.787                                    | 0.180                    | 0.3331      | 0.4177       |  |
| 0.185             | 0.3508      | 0.4399       | 1.896                                    | 0.185             | 0.3297      | 0.4134       | 1.782                                    | 0.185                    | 0.3410      | 0.4276       |  |
| 0.190             | 0.3590      | 0.4501       | 1.890                                    | 0.190             | 0.3377      | 0.4234       | 1.777                                    | 0.190                    | 0.3490      | 0.4376       |  |
| 0.195             | 0.3668      | 0.4599       | 1.881                                    | 0.195             | 0.3457      | 0.4335       | 1.773                                    | 0.195                    | 0.3570      | 0.4476       |  |
| 0.200             | 0.3745      | 0.4689       | 1.872                                    | 0.200             | 0.3539      | 0.4431       | 1.769                                    | 0.200                    | 0.3650      | 0.4570       |  |
| 0.205             | 0.3822      | 0.4792       | 1.863                                    | 0.205             | 0.3616      | 0.4534       | 1.765                                    | 0.205                    | 0.3726      | 0.4672       |  |

Note :—In commercial sugars there is a small amount of non-sugar substance which reduces Fehling's solution, and in accurate analysis this must be allowed for. (See next page.)

### *Preparation of Basic Lead Acetate*

3 parts of lead acetate and 1 part of litharge are well mixed with  $\frac{1}{2}$  part of water, and heated on the water-bath until the original yellow mixture has become reddish. The remainder to make 10 parts of water is added, the mixture allowed to settle, and filtered. The filtrate should be clear and colourless, and of Sp. Gr. 1.235–1.240.

### *Preparation of Alumina Cream.*

A 10 per cent. solution of alum is precipitated with ammonia, the precipitate filtered and washed free from ammonia, after which it is suspended in water to form a cream

*Correction for non-sugar substances* which reduce Fehling's solution:—The principle is to ferment away sugars with brewers' yeast and to determine the reducing power after fermentation; the CuO so determined has been produced by non-sugar substances. The method adopted for ascertaining the reducing power previous to fermentation must also be used for the determination after fermentation, and the details as to quantities will vary accordingly.

The following is an example of the determination of non-sugar reducing substances according to the method of Brown, Morris and Millar.

50 cc. of 10 per cent. sugar solution (= 5 grm.) are sterilised by boiling for a few minutes, allowed to cool (covered with a watch-glass), about 2 grm. of washed and pressed brewers' yeast added, and the mixture allowed to ferment at about 75°F. (24°C.) in a thermostat. When fermentation is complete (about 48–72 hours), a small amount of alumina cream is added, and the whole washed into a 100 cc. flask and made up to the mark at 60°F.

On 25 cc. (= 1.25 grm. original sample) of the clear filtrate the reducing power is determined, and on another portion the rotation in a 2 dm. tube is found.

The CuO  $\times$  80 gives the CuO reduced by the non-sugar substances in 100 grm. of the sample.

### DETERMINATION OF INVERT SUGAR BY CLERGET METHOD.

The percentage of sucrose is first determined by the Clerget method as under determination of cane sugar by inversion method (a), the direct reading before inversion being determined after clarifying the solution with lead acetate and alumina cream.

$$\text{Per cent. invert sugar} = \frac{(\% \text{ sucrose} - D) 105.3}{44 - \frac{t}{2}}$$

where D = direct reading corresponding to normal weight.

## II. Determination of the Cane Sugar in Commercial Products.

### 1. *Soleil-Ventzke-Scheibler polarimeter method, using Schmitz's table (following page).*

This method is used for determining sucrose in beetroot juice, in "thin juice," and in the Weinberg method of estimating the apparent purity of the crude juice from the sugar cane.

100 cc. of the juice is introduced into a flask which is graduated to hold 100 and 110 cc. and basic lead acetate added to give a total volume of 110 cc., the mixture is well shaken and filtered. In the case of beetroot juice the solution after shaking is allowed to stand for 10-15 minutes before filtering. The rotation of the filtrate in a 200 mm. tube increased by 10%, multiplied by 0.26, and divided by the sp. gr. gives the % of sugar by weight.

Schmitz's table (see next page) renders this calculation unnecessary.

### 2. *Inversion Method.*

#### (a) *Using the Saccharimeter (Clerget's method).*

Half the normal weight (13 grm.) is dissolved in 75 cc. water in a 100 cc. flask, and 5 cc. HCl of Sp. Gr. 1.188 added. The flask is placed in a water-bath at 70°C., and the contents maintained constant at 67-70°C. for exactly 5 mins., cooled to 20°C. and diluted to the mark. If the solutions are dark, 1-2 grm. bone charcoal (previously extracted with HCl and ignited) is added, the flasks well shaken, and the solutions filtered until clear and colourless. The reading is taken in a jacketed observation tube at 20°C. The solution used for the direct reading before inversion should be clarified with lead acetate and alumina cream to precipitate active non-sugar substances.

$$\text{Per cent. sucrose} = \frac{100 S}{142.966 - \frac{t}{2}} \quad [\text{Clerget's formula}].$$

S = the change in rotation in saccharimeter degrees, calculated on the whole normal weight (26 grm.).

The following formula is used in case raffinose is present, and is applicable only when the solution contains negligible traces of invert sugar.

$$\text{Per cent. sucrose} = \frac{0.5124 P - I_{20}}{0.839}$$

P = the direct polarisation and  $I_{20}$  = the polarisation at 20°C. after inversion calculated to the whole normal weight.

$$I_{20} = I_t + 0.0038 S (20 - t).$$



# Sucrose Solutions (Schmitz)

Polarimeter, taking into consideration the variable Specific Rotatory Power volume of lead acetate solution.

| Brix and corresponding Sp. Gr. |        |        |        |        |        |        |        |        |        | Rotation<br>degrees. | Brix<br>12.5—20.0    |          |
|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|----------------------|----------------------|----------|
| 5.5                            | 6.0    | 6.5    | 7.0    | 7.5    | 8.0    | 8.5    | 9.0    | 9.5    | 10.0   |                      | Tenths of<br>degree. | % Sugar. |
| 1.0217                         | 1.0237 | 1.0258 | 1.0278 | 1.0298 | 1.0319 | 1.0339 | 1.0360 | 1.0381 | 1.0401 |                      |                      |          |
| 0.28                           | 0.28   | 0.28   | 0.28   | 0.28   | 0.28   | 0.28   | 0.28   | 0.28   | 0.28   | 1                    | 0.1                  | 0.03     |
| 0.56                           | 0.56   | 0.56   | 0.56   | 0.55   | 0.55   | 0.55   | 0.55   | 0.55   | 0.55   | 2                    | 0.2                  | 0.05     |
| 0.84                           | 0.84   | 0.84   | 0.83   | 0.83   | 0.83   | 0.83   | 0.83   | 0.83   | 0.82   | 3                    | 0.3                  | 0.08     |
| 1.12                           | 1.12   | 1.11   | 1.11   | 1.11   | 1.11   | 1.11   | 1.10   | 1.10   | 1.10   | 4                    | 0.4                  | 0.11     |
| 1.40                           | 1.40   | 1.39   | 1.39   | 1.39   | 1.38   | 1.38   | 1.38   | 1.38   | 1.37   | 5                    | 0.5                  | 0.13     |
| 1.68                           | 1.67   | 1.67   | 1.67   | 1.66   | 1.66   | 1.66   | 1.66   | 1.65   | 1.65   | 6                    | 0.6                  | 0.16     |
| 1.96                           | 1.95   | 1.95   | 1.95   | 1.94   | 1.94   | 1.93   | 1.93   | 1.93   | 1.92   | 7                    | 0.7                  | 0.19     |
| 2.24                           | 2.23   | 2.23   | 2.22   | 2.22   | 2.22   | 2.21   | 2.21   | 2.20   | 2.20   | 8                    | 0.8                  | 0.21     |
| 2.52                           | 2.51   | 2.51   | 2.50   | 2.50   | 2.49   | 2.49   | 2.48   | 2.48   | 2.47   | 9                    | 0.9                  | 0.24     |
| 2.80                           | 2.79   | 2.79   | 2.78   | 2.78   | 2.77   | 2.76   | 2.76   | 2.75   | 2.75   | 10                   |                      |          |
| 3.08                           | 3.07   | 3.06   | 3.06   | 3.05   | 3.05   | 3.04   | 3.03   | 3.03   | 3.02   | 11                   |                      |          |
| 3.36                           | 3.35   | 3.34   | 3.34   | 3.33   | 3.32   | 3.32   | 3.31   | 3.30   | 3.30   | 12                   |                      |          |
| 3.64                           | 3.63   | 3.62   | 3.61   | 3.61   | 3.60   | 3.59   | 3.59   | 3.58   | 3.57   | 13                   |                      |          |
| 3.92                           | 3.91   | 3.90   | 3.89   | 3.88   | 3.88   | 3.87   | 3.86   | 3.85   | 3.85   | 14                   |                      |          |
| 4.19                           | 4.19   | 4.18   | 4.17   | 4.16   | 4.15   | 4.15   | 4.14   | 4.13   | 4.12   | 15                   |                      |          |
| 4.47                           | 4.47   | 4.46   | 4.45   | 4.44   | 4.43   | 4.42   | 4.41   | 4.40   | 4.40   | 16                   |                      |          |
| 4.76                           | 4.75   | 4.74   | 4.73   | 4.72   | 4.71   | 4.70   | 4.69   | 4.68   | 4.67   | 17                   |                      |          |
| 5.03                           | 5.02   | 5.01   | 5.00   | 4.99   | 4.99   | 4.97   | 4.97   | 4.96   | 4.95   | 18                   |                      |          |
| 5.32                           | 5.31   | 5.29   | 5.28   | 5.27   | 5.26   | 5.25   | 5.24   | 5.23   | 5.22   | 19                   |                      |          |
|                                | 5.58   | 5.57   | 5.56   | 5.55   | 5.54   | 5.53   | 5.52   | 5.51   | 5.50   | 20                   |                      |          |
|                                | 5.86   | 5.85   | 5.84   | 5.83   | 5.82   | 5.81   | 5.79   | 5.78   | 5.77   | 21                   | 0.1                  | 0.03     |
|                                |        | 6.13   | 6.12   | 6.11   | 6.09   | 6.08   | 6.07   | 6.06   | 6.05   | 22                   | 0.2                  | 0.05     |
|                                |        | 6.41   | 6.40   | 6.38   | 6.37   | 6.36   | 6.35   | 6.33   | 6.32   | 23                   | 0.3                  | 0.08     |
|                                |        |        | 6.67   | 6.66   | 6.65   | 6.64   | 6.62   | 6.61   | 6.60   | 24                   | 0.4                  | 0.11     |
|                                |        |        |        | 6.94   | 6.93   | 6.91   | 6.90   | 6.89   | 6.87   | 25                   | 0.5                  | 0.13     |
|                                |        |        |        | 7.22   | 7.20   | 7.19   | 7.17   | 7.16   | 7.15   | 26                   | 0.6                  | 0.16     |
|                                |        |        |        |        | 7.48   | 7.46   | 7.45   | 7.44   | 7.42   | 27                   | 0.7                  | 0.18     |
|                                |        |        |        |        | 7.76   | 7.74   | 7.73   | 7.71   | 7.70   | 28                   | 0.8                  | 0.21     |
|                                |        |        |        |        |        | 8.02   | 8.00   | 7.99   | 7.97   | 29                   | 0.9                  | 0.23     |
|                                |        |        |        |        |        |        | 8.28   | 8.26   | 8.25   | 30                   |                      |          |
|                                |        |        |        |        |        |        | 8.55   | 8.54   | 8.52   | 31                   |                      |          |
|                                |        |        |        |        |        |        | 8.83   | 8.81   | 8.80   | 32                   |                      |          |
|                                |        |        |        |        |        |        |        | 9.08   | 9.07   | 33                   |                      |          |
|                                |        |        |        |        |        |        |        |        | 9.35   | 34                   |                      |          |
|                                |        |        |        |        |        |        |        |        | 9.62   | 35                   |                      |          |



| Brix<br>0.5—12.0     |          | Rotation<br>degrees. | Brix and corresponding Sp. Gr. |        |        |        |        |        |        |        |        |        |
|----------------------|----------|----------------------|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Tenths of<br>degree. | % Sugar. |                      | 10.5                           | 11.0   | 11.5   | 12.0   | 12.5   | 13.0   | 13.5   | 14.0   | 14.5   | 15.0   |
|                      |          |                      | 1.0422                         | 1.0443 | 1.0464 | 1.0485 | 1.0506 | 1.0528 | 1.0549 | 1.0570 | 1.0592 | 1.0613 |
| 0.1                  | 0.03     | 1                    | 0.28                           | 0.27   | 0.27   | 0.27   | 0.27   | 0.27   | 0.27   | 0.27   | 0.27   | 0.27   |
| 0.2                  | 0.06     | 2                    | 0.55                           | 0.55   | 0.55   | 0.55   | 0.54   | 0.54   | 0.54   | 0.54   | 0.54   | 0.54   |
| 0.3                  | 0.08     | 3                    | 0.82                           | 0.82   | 0.82   | 0.82   | 0.82   | 0.81   | 0.81   | 0.81   | 0.81   | 0.81   |
| 0.4                  | 0.11     | 4                    | 1.10                           | 1.10   | 1.09   | 1.09   | 1.09   | 1.09   | 1.08   | 1.08   | 1.08   | 1.08   |
| 0.5                  | 0.14     | 5                    | 1.37                           | 1.37   | 1.36   | 1.36   | 1.36   | 1.36   | 1.35   | 1.35   | 1.35   | 1.35   |
| 0.6                  | 0.17     | 6                    | 1.64                           | 1.64   | 1.64   | 1.64   | 1.63   | 1.63   | 1.62   | 1.62   | 1.62   | 1.62   |
| 0.7                  | 0.19     | 7                    | 1.92                           | 1.91   | 1.91   | 1.91   | 1.90   | 1.90   | 1.89   | 1.89   | 1.89   | 1.88   |
| 0.8                  | 0.22     | 8                    | 2.19                           | 2.19   | 2.18   | 2.18   | 2.18   | 2.17   | 2.17   | 2.16   | 2.16   | 2.15   |
| 0.9                  | 0.25     | 9                    | 2.47                           | 2.46   | 2.46   | 2.45   | 2.45   | 2.44   | 2.44   | 2.43   | 2.43   | 2.42   |
|                      |          | 10                   | 2.74                           | 2.74   | 2.73   | 2.73   | 2.72   | 2.71   | 2.71   | 2.70   | 2.70   | 2.69   |
|                      |          | 11                   | 3.02                           | 3.01   | 3.00   | 3.00   | 2.99   | 2.99   | 2.98   | 2.97   | 2.97   | 2.96   |
|                      |          | 12                   | 3.29                           | 3.28   | 3.28   | 3.27   | 3.26   | 3.26   | 3.25   | 3.24   | 3.24   | 3.23   |
|                      |          | 13                   | 3.56                           | 3.56   | 3.55   | 3.54   | 3.54   | 3.53   | 3.52   | 3.51   | 3.51   | 3.50   |
|                      |          | 14                   | 3.84                           | 3.83   | 3.82   | 3.82   | 3.81   | 3.80   | 3.79   | 3.78   | 3.78   | 3.77   |
|                      |          | 15                   | 4.11                           | 4.11   | 4.10   | 4.09   | 4.08   | 4.07   | 4.06   | 4.06   | 4.05   | 4.04   |
|                      |          | 16                   | 4.39                           | 4.38   | 4.37   | 4.36   | 4.35   | 4.34   | 4.33   | 4.33   | 4.32   | 4.31   |
|                      |          | 17                   | 4.66                           | 4.65   | 4.64   | 4.63   | 4.62   | 4.62   | 4.61   | 4.60   | 4.59   | 4.58   |
|                      |          | 18                   | 4.93                           | 4.93   | 4.91   | 4.91   | 4.90   | 4.89   | 4.88   | 4.87   | 4.86   | 4.85   |
|                      |          | 19                   | 5.21                           | 5.20   | 5.19   | 5.18   | 5.17   | 5.16   | 5.15   | 5.14   | 5.13   | 5.12   |
|                      |          | 20                   | 5.49                           | 5.47   | 5.46   | 5.45   | 5.44   | 5.43   | 5.42   | 5.41   | 5.40   | 5.39   |
| 0.1                  | 0.03     | 21                   | 5.76                           | 5.75   | 5.74   | 5.73   | 5.71   | 5.70   | 5.69   | 5.68   | 5.67   | 5.66   |
| 0.2                  | 0.06     | 22                   | 6.03                           | 6.02   | 6.01   | 6.00   | 5.99   | 5.97   | 5.96   | 5.95   | 5.94   | 5.93   |
| 0.3                  | 0.08     | 23                   | 6.31                           | 6.30   | 6.28   | 6.27   | 6.26   | 6.24   | 6.23   | 6.22   | 6.21   | 6.20   |
| 0.4                  | 0.11     | 24                   | 6.58                           | 6.57   | 6.56   | 6.54   | 6.53   | 6.52   | 6.50   | 6.49   | 6.48   | 6.46   |
| 0.5                  | 0.14     | 25                   | 6.86                           | 6.84   | 6.83   | 6.82   | 6.80   | 6.79   | 6.78   | 6.76   | 6.75   | 6.73   |
| 0.6                  | 0.17     | 26                   | 7.13                           | 7.12   | 7.10   | 7.09   | 7.07   | 7.06   | 7.05   | 7.03   | 7.02   | 7.00   |
| 0.7                  | 0.19     | 27                   | 7.41                           | 7.39   | 7.38   | 7.36   | 7.35   | 7.33   | 7.32   | 7.30   | 7.29   | 7.27   |
| 0.8                  | 0.22     | 28                   | 7.68                           | 7.66   | 7.65   | 7.63   | 7.62   | 7.60   | 7.59   | 7.57   | 7.56   | 7.54   |
| 0.9                  | 0.25     | 29                   | 7.96                           | 7.94   | 7.92   | 7.91   | 7.89   | 7.87   | 7.86   | 7.84   | 7.83   | 7.81   |
|                      |          | 30                   | 8.23                           | 8.21   | 8.20   | 8.18   | 8.16   | 8.15   | 8.13   | 8.11   | 8.10   | 8.08   |
|                      |          | 31                   | 8.50                           | 8.49   | 8.47   | 8.45   | 8.44   | 8.42   | 8.40   | 8.39   | 8.37   | 8.35   |
|                      |          | 32                   | 8.78                           | 8.76   | 8.74   | 8.73   | 8.71   | 8.69   | 8.67   | 8.66   | 8.64   | 8.62   |
|                      |          | 33                   | 9.05                           | 9.03   | 9.02   | 9.00   | 8.98   | 8.96   | 8.94   | 8.93   | 8.91   | 8.89   |
|                      |          | 34                   | 9.33                           | 9.31   | 9.29   | 9.27   | 9.25   | 9.23   | 9.22   | 9.20   | 9.18   | 9.16   |
|                      |          | 35                   | 9.60                           | 9.58   | 9.56   | 9.54   | 9.53   | 9.51   | 9.49   | 9.47   | 9.45   | 9.43   |
|                      |          | 36                   | 9.88                           | 9.86   | 9.84   | 9.82   | 9.80   | 9.78   | 9.76   | 9.74   | 9.72   | 9.70   |
|                      |          | 37                   | 10.15                          | 10.13  | 10.11  | 10.09  | 10.07  | 10.05  | 10.03  | 10.01  | 9.99   | 9.97   |
|                      |          | 38                   |                                | 10.40  | 10.38  | 10.36  | 10.34  | 10.32  | 10.30  | 10.28  | 10.26  | 10.24  |
|                      |          | 39                   |                                | 10.68  | 10.66  | 10.64  | 10.61  | 10.59  | 10.57  | 10.55  | 10.53  | 10.51  |



## Brix and corresponding Sp. Gr.

| Brix and corresponding Sp. Gr. |        |        |        |        |        |        |        |        |        | Rotation<br>degrees. | Brix<br>12.5—20.0    |         |
|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|----------------------|----------------------|---------|
| 15.5                           | 16.0   | 16.5   | 17.0   | 17.5   | 18.0   | 18.5   | 19.0   | 19.5   | 20.0   |                      | Tenths of<br>degree. | % Sugar |
| 10.635                         | 1.0657 | 1.0678 | 1.0700 | 1.0722 | 1.0744 | 1.0766 | 1.0788 | 1.0811 | 1.0833 |                      |                      |         |
| 0.27                           | 0.27   | 0.27   | 0.27   | 0.27   | 0.27   | 0.27   | 0.27   | 0.27   | 0.26   | 1                    | 0.1                  | 0.03    |
| 0.54                           | 0.54   | 0.54   | 0.53   | 0.53   | 0.53   | 0.53   | 0.53   | 0.53   | 0.53   | 2                    | 0.2                  | 0.05    |
| 0.81                           | 0.80   | 0.80   | 0.80   | 0.80   | 0.80   | 0.80   | 0.79   | 0.79   | 0.79   | 3                    | 0.3                  | 0.08    |
| 1.08                           | 1.07   | 1.07   | 1.07   | 1.07   | 1.06   | 1.06   | 1.06   | 1.06   | 1.06   | 4                    | 0.4                  | 0.11    |
| 1.34                           | 1.34   | 1.34   | 1.34   | 1.33   | 1.33   | 1.33   | 1.32   | 1.32   | 1.32   | 5                    | 0.5                  | 0.13    |
| 1.61                           | 1.61   | 1.61   | 1.60   | 1.60   | 1.60   | 1.59   | 1.59   | 1.59   | 1.58   | 6                    | 0.6                  | 0.16    |
| 1.88                           | 1.88   | 1.87   | 1.87   | 1.86   | 1.86   | 1.86   | 1.85   | 1.85   | 1.85   | 7                    | 0.7                  | 0.19    |
| 2.15                           | 2.15   | 2.14   | 2.14   | 2.13   | 2.13   | 2.12   | 2.12   | 2.12   | 2.11   | 8                    | 0.8                  | 0.21    |
| 2.42                           | 2.41   | 2.41   | 2.40   | 2.40   | 2.39   | 2.39   | 2.38   | 2.38   | 2.37   | 9                    | 0.9                  | 0.24    |
| 2.69                           | 2.68   | 2.68   | 2.67   | 2.67   | 2.66   | 2.65   | 2.65   | 2.64   | 2.64   | 10                   |                      |         |
| 2.95                           | 2.95   | 2.94   | 2.94   | 2.93   | 2.92   | 2.92   | 2.91   | 2.91   | 2.90   | 11                   |                      |         |
| 3.22                           | 3.22   | 3.21   | 3.20   | 3.20   | 3.19   | 3.18   | 3.18   | 3.17   | 3.17   | 12                   |                      |         |
| 3.49                           | 3.49   | 3.48   | 3.47   | 3.46   | 3.46   | 3.45   | 3.44   | 3.44   | 3.43   | 13                   |                      |         |
| 3.76                           | 3.75   | 3.75   | 3.74   | 3.73   | 3.72   | 3.72   | 3.71   | 3.70   | 3.69   | 14                   |                      |         |
| 4.03                           | 4.02   | 4.02   | 4.01   | 4.00   | 3.99   | 3.98   | 3.97   | 3.97   | 3.96   | 15                   |                      |         |
| 4.30                           | 4.29   | 4.28   | 4.27   | 4.26   | 4.26   | 4.25   | 4.24   | 4.23   | 4.22   | 16                   |                      |         |
| 4.57                           | 4.56   | 4.55   | 4.54   | 4.53   | 4.52   | 4.51   | 4.50   | 4.49   | 4.48   | 17                   |                      |         |
| 4.84                           | 4.83   | 4.82   | 4.81   | 4.80   | 4.79   | 4.78   | 4.77   | 4.76   | 4.75   | 18                   |                      |         |
| 5.11                           | 5.10   | 5.09   | 5.08   | 5.06   | 5.05   | 5.04   | 5.03   | 5.02   | 5.01   | 19                   |                      |         |
| 5.38                           | 5.36   | 5.35   | 5.34   | 5.33   | 5.32   | 5.31   | 5.30   | 5.29   | 5.28   | 20                   |                      |         |
| 5.65                           | 5.63   | 5.62   | 5.61   | 5.60   | 5.59   | 5.58   | 5.56   | 5.55   | 5.54   | 21                   | 0.1                  | 0.03    |
| 5.91                           | 5.90   | 5.89   | 5.88   | 5.87   | 5.85   | 5.84   | 5.83   | 5.82   | 5.80   | 22                   | 0.2                  | 0.05    |
| 6.18                           | 6.17   | 6.16   | 6.14   | 6.13   | 6.12   | 6.11   | 6.09   | 6.08   | 6.07   | 23                   | 0.3                  | 0.08    |
| 6.45                           | 6.44   | 6.43   | 6.41   | 6.40   | 6.39   | 6.37   | 6.36   | 6.35   | 6.33   | 24                   | 0.4                  | 0.11    |
| 6.72                           | 6.71   | 6.69   | 6.68   | 6.67   | 6.65   | 6.64   | 6.63   | 6.61   | 6.60   | 25                   | 0.5                  | 0.13    |
| 6.99                           | 6.97   | 6.96   | 6.95   | 6.93   | 6.92   | 6.90   | 6.89   | 6.88   | 6.86   | 26                   | 0.6                  | 0.16    |
| 7.26                           | 7.24   | 7.23   | 7.21   | 7.20   | 7.18   | 7.17   | 7.15   | 7.14   | 7.13   | 27                   | 0.7                  | 0.18    |
| 7.53                           | 7.51   | 7.50   | 7.48   | 7.47   | 7.45   | 7.44   | 7.42   | 7.40   | 7.39   | 28                   | 0.8                  | 0.21    |
| 7.80                           | 7.78   | 7.77   | 7.75   | 7.73   | 7.72   | 7.70   | 7.68   | 7.67   | 7.65   | 29                   | 0.9                  | 0.23    |
| 8.06                           | 8.05   | 8.03   | 8.02   | 8.00   | 7.98   | 7.97   | 7.95   | 7.93   | 7.92   | 30                   |                      |         |
| 8.33                           | 8.32   | 8.30   | 8.28   | 8.27   | 8.25   | 8.23   | 8.21   | 8.20   | 8.18   | 31                   |                      |         |
| 8.60                           | 8.58   | 8.57   | 8.55   | 8.53   | 8.51   | 8.50   | 8.48   | 8.46   | 8.45   | 32                   |                      |         |
| 8.87                           | 8.85   | 8.84   | 8.82   | 8.80   | 8.78   | 8.76   | 8.75   | 8.73   | 8.71   | 33                   |                      |         |
| 9.14                           | 9.12   | 9.10   | 9.09   | 9.07   | 9.05   | 9.03   | 9.01   | 8.99   | 8.97   | 34                   |                      |         |
| 9.41                           | 9.39   | 9.37   | 9.35   | 9.34   | 9.31   | 9.30   | 9.28   | 9.26   | 9.24   | 35                   |                      |         |
| 9.68                           | 9.66   | 9.64   | 9.62   | 9.60   | 9.58   | 9.56   | 9.54   | 9.52   | 9.50   | 36                   |                      |         |
| 9.95                           | 9.93   | 9.91   | 9.89   | 9.87   | 9.85   | 9.83   | 9.81   | 9.79   | 9.77   | 37                   |                      |         |
| 10.22                          | 10.20  | 10.18  | 10.15  | 10.13  | 10.11  | 10.09  | 10.07  | 10.05  | 10.03  | 38                   |                      |         |
| 10.49                          | 10.46  | 10.44  | 10.42  | 10.40  | 10.38  | 10.36  | 10.34  | 10.32  | 10.29  | 39                   |                      |         |

| Brix<br>11·5—22·5    |          | Rotation<br>degrees. | Brix and corresponding Sp. Gr. |        |        |        |        |        |        |        |
|----------------------|----------|----------------------|--------------------------------|--------|--------|--------|--------|--------|--------|--------|
| Tenths of<br>degree. | % Sugar. |                      | 11·5                           | 12·0   | 12·5   | 13·0   | 13·5   | 14·0   | 14·5   | 15·0   |
|                      |          |                      | 1·0464                         | 1·0485 | 1·0506 | 1·0528 | 1·0549 | 1·0570 | 1·0592 | 1·0613 |
| 0·1                  | 0·03     | 40                   | 10·93                          | 10·91  | 10·89  | 10·86  | 10·84  | 10·82  | 10·80  | 10·78  |
| 0·2                  | 0·05     | 41                   |                                | 11·18  | 11·16  | 11·14  | 11·12  | 11·09  | 11·07  | 11·05  |
| 0·3                  | 0·08     | 42                   |                                | 11·46  | 11·43  | 11·41  | 11·39  | 11·36  | 11·34  | 11·32  |
| 0·4                  | 0·11     | 43                   |                                |        | 11·71  | 11·68  | 11·66  | 11·64  | 11·61  | 11·59  |
|                      |          | 44                   |                                |        | 11·98  | 11·95  | 11·93  | 11·91  | 11·88  | 11·86  |
| 0·5                  | 0·13     | 45                   |                                |        | 12·25  | 12·23  | 12·20  | 12·18  | 12·15  | 12·13  |
| 0·6                  | 0·16     | 46                   |                                |        |        | 12·50  | 12·47  | 12·45  | 12·42  | 12·40  |
| 0·7                  | 0·19     | 47                   |                                |        |        |        | 12·74  | 12·72  | 12·69  | 12·67  |
| 0·8                  | 0·21     | 48                   |                                |        |        |        | 13·02  | 12·99  | 12·97  | 12·94  |
| 0·9                  | 0·24     | 49                   |                                |        |        |        |        | 13·26  | 13·23  | 13·21  |
|                      |          | 50                   |                                |        |        |        |        |        | 13·50  | 13·48  |
|                      |          | 51                   |                                |        |        |        |        |        | 13·78  | 13·75  |
|                      |          | 52                   |                                |        |        |        |        |        |        | 14·02  |
|                      |          | 53                   |                                |        |        |        |        |        |        | 14·29  |
|                      |          | 54                   |                                |        |        |        |        |        |        |        |
| Brix<br>17·0—23·0    |          | 55                   |                                |        |        |        |        |        |        |        |
| Tenths of<br>degree. | % Sugar. | 56                   |                                |        |        |        |        |        |        |        |
|                      |          | 57                   |                                |        |        |        |        |        |        |        |
|                      |          | 58                   |                                |        |        |        |        |        |        |        |
|                      |          | 59                   |                                |        |        |        |        |        |        |        |
| 0·1                  | 0·03     | 60                   |                                |        |        |        |        |        |        |        |
| 0·2                  | 0·05     | 61                   |                                |        |        |        |        |        |        |        |
| 0·3                  | 0·08     | 62                   |                                |        |        |        |        |        |        |        |
| 0·4                  | 0·11     | 63                   |                                |        |        |        |        |        |        |        |
|                      |          | 64                   |                                |        |        |        |        |        |        |        |
| 0·5                  | 0·13     | 65                   |                                |        |        |        |        |        |        |        |
| 0·6                  | 0·16     | 66                   |                                |        |        |        |        |        |        |        |
| 0·7                  | 0·18     | 67                   |                                |        |        |        |        |        |        |        |
| 0·8                  | 0·21     | 68                   |                                |        |        |        |        |        |        |        |
| 0·9                  | 0·24     | 69                   |                                |        |        |        |        |        |        |        |
|                      |          | 70                   |                                |        |        |        |        |        |        |        |
|                      |          | 71                   |                                |        |        |        |        |        |        |        |
|                      |          | 72                   |                                |        |        |        |        |        |        |        |
|                      |          | 73                   |                                |        |        |        |        |        |        |        |
|                      |          | 74                   |                                |        |        |        |        |        |        |        |
|                      |          | 75                   |                                |        |        |        |        |        |        |        |
|                      |          | 76                   |                                |        |        |        |        |        |        |        |
|                      |          | 77                   |                                |        |        |        |        |        |        |        |
|                      |          | 78                   |                                |        |        |        |        |        |        |        |
|                      |          | 79                   |                                |        |        |        |        |        |        |        |
|                      |          | 80                   |                                |        |        |        |        |        |        |        |

| Brix and corresponding Sp. Gr. |        |        |        |        |        |        |        |        | Rotation<br>degrees. | Brix<br>23·0—24·0    |         |
|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|----------------------|----------------------|---------|
| 15·5                           | 16·0   | 16·5   | 17·0   | 17·5   | 18·0   | 18·5   | 19·0   | 19·5   |                      | Tenths of<br>degree. | % Sugar |
| 1·0635                         | 1·0657 | 1·0678 | 1·0700 | 1·0722 | 1·0744 | 1·0766 | 1·0788 | 1·0811 |                      |                      |         |
| 10·76                          | 10·73  | 10·71  | 10·69  | 10·67  | 10·64  | 10·62  | 10·60  | 10·58  | 40                   |                      |         |
| 11·03                          | 11·00  | 10·98  | 10·96  | 10·94  | 10·91  | 10·89  | 10·87  | 10·85  | 41                   | 0·1                  | 0·03    |
| 11·29                          | 11·27  | 11·25  | 11·23  | 11·20  | 11·18  | 11·16  | 11·13  | 11·11  | 42                   | 0·2                  | 0·05    |
| 11·56                          | 11·54  | 11·52  | 11·49  | 11·47  | 11·45  | 11·42  | 11·40  | 11·38  | 43                   | 0·3                  | 0·08    |
| 11·83                          | 11·81  | 11·79  | 11·76  | 11·74  | 11·71  | 11·69  | 11·66  | 11·64  | 44                   | 0·4                  | 0·10    |
| 12·10                          | 12·08  | 12·05  | 12·03  | 12·01  | 11·98  | 11·96  | 11·93  | 11·91  | 45                   | 0·5                  | 0·13    |
| 12·37                          | 12·35  | 12·32  | 12·30  | 12·27  | 12·25  | 12·22  | 12·20  | 12·17  | 46                   | 0·6                  | 0·16    |
| 12·64                          | 12·61  | 12·59  | 12·56  | 12·54  | 12·51  | 12·49  | 12·46  | 12·44  | 47                   | 0·7                  | 0·18    |
| 12·91                          | 12·88  | 12·86  | 12·83  | 12·81  | 12·78  | 12·75  | 12·73  | 12·70  | 48                   | 0·8                  | 0·21    |
| 13·18                          | 13·15  | 13·13  | 13·10  | 13·07  | 13·05  | 13·02  | 12·99  | 12·97  | 49                   | 0·9                  | 0·23    |
| 13·45                          | 13·42  | 13·40  | 13·37  | 13·34  | 13·31  | 13·29  | 13·26  | 13·23  | 50                   |                      |         |
| 13·72                          | 13·69  | 13·66  | 13·64  | 13·61  | 13·58  | 13·55  | 13·52  | 13·50  | 51                   |                      |         |
| 13·99                          | 13·96  | 13·93  | 13·90  | 13·88  | 13·85  | 13·82  | 13·79  | 13·76  | 52                   |                      |         |
| 14·26                          | 14·23  | 14·20  | 14·17  | 14·14  | 14·11  | 14·08  | 14·05  | 14·03  | 53                   |                      |         |
| 14·58                          | 14·50  | 14·47  | 14·44  | 14·41  | 14·38  | 14·35  | 14·32  | 14·29  | 54                   |                      |         |
| 14·80                          | 14·77  | 14·74  | 14·71  | 14·68  | 14·65  | 14·62  | 14·59  | 14·56  | 55                   |                      |         |
|                                | 15·03  | 15·00  | 14·97  | 14·94  | 14·91  | 14·88  | 14·85  | 14·82  | 56                   |                      |         |
|                                | 15·30  | 15·27  | 15·24  | 15·21  | 15·18  | 15·15  | 15·12  | 15·09  | 57                   |                      |         |
|                                | 15·57  | 15·54  | 15·51  | 15·48  | 15·45  | 15·42  | 15·38  | 15·35  | 58                   |                      |         |
|                                |        | 15·81  | 15·78  | 15·75  | 15·71  | 15·68  | 15·65  | 15·62  | 59                   |                      |         |
|                                |        |        | 16·05  | 16·01  | 15·98  | 15·95  | 15·92  | 15·88  | 60                   |                      |         |
|                                |        |        | 16·31  | 16·28  | 16·25  | 16·21  | 16·18  | 16·15  | 61                   | 0·1                  | 0·03    |
|                                |        |        |        | 16·55  | 16·52  | 16·48  | 16·45  | 16·41  | 62                   | 0·2                  | 0·05    |
|                                |        |        |        | 16·82  | 16·78  | 16·75  | 16·71  | 16·68  | 63                   | 0·3                  | 0·08    |
|                                |        |        |        |        | 17·05  | 17·01  | 16·98  | 16·94  | 64                   | 0·4                  | 0·10    |
|                                |        |        |        |        | 17·32  | 17·28  | 17·24  | 17·21  | 65                   | 0·5                  | 0·13    |
|                                |        |        |        |        |        | 17·55  | 17·51  | 17·47  | 66                   | 0·6                  | 0·16    |
|                                |        |        |        |        |        | 17·81  | 17·78  | 17·74  | 67                   | 0·7                  | 0·18    |
|                                |        |        |        |        |        |        | 18·04  | 18·00  | 68                   | 0·8                  | 0·21    |
|                                |        |        |        |        |        |        | 18·31  | 18·27  | 69                   | 0·9                  | 0·23    |
|                                |        |        |        |        |        |        |        | 18·53  | 70                   |                      |         |
|                                |        |        |        |        |        |        |        |        | 71                   |                      |         |
|                                |        |        |        |        |        |        |        |        | 72                   |                      |         |
|                                |        |        |        |        |        |        |        |        | 73                   |                      |         |
|                                |        |        |        |        |        |        |        |        | 74                   |                      |         |
|                                |        |        |        |        |        |        |        |        | 75                   |                      |         |
|                                |        |        |        |        |        |        |        |        | 76                   |                      |         |
|                                |        |        |        |        |        |        |        |        | 77                   |                      |         |
|                                |        |        |        |        |        |        |        |        | 78                   |                      |         |
|                                |        |        |        |        |        |        |        |        | 79                   |                      |         |
|                                |        |        |        |        |        |        |        |        | 80                   |                      |         |

| Brix.<br>23.0—24.0   |          | Rotation<br>degrees. | Brix and corresponding Sp. Gr. |        |        |        |        |        |        |        |        |
|----------------------|----------|----------------------|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Tenths of<br>degree. | % Sugar. |                      | 20.0                           | 20.5   | 21.0   | 21.5   | 22.0   | 22.5   | 23.0   | 23.5   | 24.0   |
|                      |          |                      | 1.0833                         | 1.0855 | 1.0878 | 1.0900 | 1.0923 | 1.0946 | 1.0969 | 1.0992 | 1.1015 |
| 0.1                  | 0.03     | 40                   | 10.56                          | 10.54  | 10.52  | 10.49  | 10.47  | 10.45  | 10.43  | 10.41  | 10.38  |
| 0.2                  | 0.05     | 41                   | 10.82                          | 10.80  | 10.78  | 10.76  | 10.74  | 10.71  | 10.69  | 10.67  | 10.65  |
| 0.3                  | 0.08     | 42                   | 11.09                          | 11.07  | 11.04  | 11.02  | 11.00  | 10.97  | 10.95  | 10.93  | 10.90  |
| 0.4                  | 0.11     | 43                   | 11.35                          | 11.33  | 11.31  | 11.28  | 11.26  | 11.24  | 11.21  | 11.19  | 11.17  |
|                      |          | 44                   | 11.62                          | 11.59  | 11.57  | 11.55  | 11.52  | 11.50  | 11.47  | 11.45  | 11.42  |
| 0.5                  | 0.13     | 45                   | 11.88                          | 11.86  | 11.83  | 11.81  | 11.78  | 11.76  | 11.73  | 11.71  | 11.69  |
| 0.6                  | 0.16     | 46                   | 12.15                          | 12.12  | 12.09  | 12.07  | 12.05  | 12.02  | 12.00  | 11.97  | 11.94  |
| 0.7                  | 0.18     | 47                   | 12.41                          | 12.39  | 12.36  | 12.33  | 12.31  | 12.28  | 12.26  | 12.23  | 12.21  |
| 0.8                  | 0.21     | 48                   | 12.67                          | 12.65  | 12.62  | 12.60  | 12.57  | 12.54  | 12.52  | 12.49  | 12.47  |
| 0.9                  | 0.23     | 49                   | 12.94                          | 12.91  | 12.88  | 12.86  | 12.83  | 12.81  | 12.78  | 12.75  | 12.73  |
|                      |          | 50                   | 13.20                          | 13.18  | 13.15  | 13.12  | 13.09  | 13.07  | 13.04  | 13.01  | 12.99  |
|                      |          | 51                   | 13.47                          | 13.44  | 13.41  | 13.39  | 13.36  | 13.33  | 13.30  | 13.27  | 13.25  |
|                      |          | 52                   | 13.73                          | 13.70  | 13.68  | 13.65  | 13.62  | 13.59  | 13.56  | 13.53  | 13.51  |
|                      |          | 53                   | 14.00                          | 13.97  | 13.94  | 13.91  | 13.88  | 13.85  | 13.82  | 13.79  | 13.77  |
|                      |          | 54                   | 14.26                          | 14.23  | 14.20  | 14.17  | 14.14  | 14.11  | 14.08  | 14.04  | 14.02  |
|                      |          | 55                   | 14.53                          | 14.50  | 14.47  | 14.44  | 14.41  | 14.38  | 14.35  | 14.32  | 14.29  |
|                      |          | 56                   | 14.79                          | 14.76  | 14.73  | 14.70  | 14.67  | 14.64  | 14.61  | 14.58  | 14.55  |
|                      |          | 57                   | 15.06                          | 15.02  | 14.99  | 14.96  | 14.93  | 14.90  | 14.87  | 14.84  | 14.81  |
|                      |          | 58                   | 15.32                          | 15.29  | 15.26  | 15.23  | 15.19  | 15.16  | 15.13  | 15.10  | 15.07  |
|                      |          | 59                   | 15.58                          | 15.55  | 15.52  | 15.49  | 15.46  | 15.42  | 15.39  | 15.36  | 15.33  |
|                      |          | 60                   | 15.85                          | 15.82  | 15.78  | 15.75  | 15.72  | 15.69  | 15.65  | 15.62  | 15.59  |
| 0.1                  | 0.03     | 61                   | 16.11                          | 16.08  | 16.05  | 16.01  | 15.98  | 15.95  | 15.91  | 15.88  | 15.85  |
| 0.2                  | 0.05     | 62                   | 16.38                          | 16.35  | 16.31  | 16.28  | 16.24  | 16.21  | 16.18  | 16.14  | 16.11  |
| 0.3                  | 0.08     | 63                   | 16.64                          | 16.61  | 16.57  | 16.54  | 16.51  | 16.47  | 16.44  | 16.40  | 16.37  |
| 0.4                  | 0.10     | 64                   | 16.91                          | 16.87  | 16.84  | 16.80  | 16.77  | 16.73  | 16.70  | 16.66  | 16.63  |
| 0.5                  | 0.13     | 65                   | 17.17                          | 17.14  | 17.10  | 17.07  | 17.03  | 17.00  | 16.96  | 16.92  | 16.89  |
| 0.6                  | 0.16     | 66                   | 17.44                          | 17.40  | 17.37  | 17.33  | 17.29  | 17.26  | 17.22  | 17.19  | 17.15  |
| 0.7                  | 0.18     | 67                   | 17.70                          | 17.67  | 17.63  | 17.59  | 17.56  | 17.52  | 17.48  | 17.45  | 17.41  |
| 0.8                  | 0.21     | 68                   | 17.97                          | 17.93  | 17.89  | 17.86  | 17.82  | 17.78  | 17.74  | 17.71  | 17.67  |
| 0.9                  | 0.23     | 69                   | 18.23                          | 18.19  | 18.16  | 18.12  | 18.08  | 18.04  | 18.00  | 17.97  | 17.93  |
|                      |          | 70                   | 18.50                          | 18.46  | 18.42  | 18.38  | 18.35  | 18.31  | 18.27  | 18.23  | 18.19  |
|                      |          | 71                   | 18.76                          | 18.72  | 18.68  | 18.65  | 18.61  | 18.57  | 18.53  | 18.49  | 18.45  |
|                      |          | 72                   | 19.03                          | 18.99  | 18.95  | 18.91  | 18.87  | 18.83  | 18.79  | 18.75  | 18.71  |
|                      |          | 73                   |                                | 19.25  | 19.21  | 19.17  | 19.13  | 19.09  | 19.05  | 19.01  | 18.97  |
|                      |          | 74                   |                                | 19.52  | 19.48  | 19.44  | 19.40  | 19.35  | 19.31  | 19.27  | 19.23  |
|                      |          | 75                   |                                | 19.78  | 19.74  | 19.70  | 19.66  | 19.62  | 19.57  | 19.53  | 19.49  |
|                      |          | 76                   |                                |        | 20.00  | 19.96  | 19.92  | 19.88  | 19.84  | 19.80  | 19.75  |
|                      |          | 77                   |                                |        | 20.27  | 20.22  | 20.18  | 20.14  | 20.10  | 20.06  | 20.01  |
|                      |          | 78                   |                                |        |        | 20.49  | 20.45  | 20.40  | 20.36  | 20.32  | 20.27  |
|                      |          | 79                   |                                |        |        | 20.75  | 20.71  | 20.66  | 20.62  | 20.58  | 20.54  |
|                      |          | 80                   |                                |        |        |        | 20.97  | 20.93  | 20.88  | 20.84  | 20.80  |

(b) *Using Polarimeter graduated in circular degrees.*

*Acid inversion method.*

The reading on a 10 "per cent." solution, containing 10 gm. in 100 cc. solution, is taken at 20°C. in a 2 dm. tube. 25 cc. of a 20 per cent. solution are placed in a 50 cc. flask, 2.5 gm. of citric acid added and the liquid boiled for 10 minutes. Davis and Daish have shown that cane sugar is completely hydrolysed by boiling with a 10 per cent. solution of citric acid for 10 minutes. After inversion the solution is neutralised and made up to 50 cc., giving a solution equivalent to a 10-per cent. solution of the original sample. If necessary the liquid should be decolorised. A reading is now taken in a 2 dm. tube at 20°C.

$$\text{Per cent. sucrose in sample} = \frac{C \times 10}{1.755}$$

C = total change in reading in *circular* degrees due to inversion, calculated on 10 per cent. solution, in a 2 dm. tube.

*Invertase (Yeast) Inversion Method.*

The principle is exactly the same as in the acid inversion method, except that yeast is used to invert the sucrose.

A reading is taken before inversion on a 10 per cent. solution in a 2 dm. tube; 25 cc. of a 20 per cent. solution is measured into a 50 cc. flask, 0.5 gm. of washed pressed yeast added after the solution has been brought to 50°C. (122°F.), and the mixture maintained at 50–53°C. for 6 hours, after which alumina cream is added, and the mixture cooled and diluted to 50 cc. The reading on the filtrate is taken in a 2 dm. tube, and the per cent. sucrose in the sample calculated by the formula given above.

The yeast inversion is more accurate than acid inversion, since lævulose is very sensitive to acid, by which it is easily destroyed; the acid method, however, takes much less time.

3. *Gravimetric Determination of the Sucrose in Cane Sugars.*

1. CuO due to invert sugar, etc., already present in sample: generally 20 cc. of a 10 per cent. solution is a suitable quantity

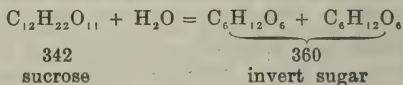
2. CuO from 10 cc. of a 2 per cent. solution after inversion of the sucrose.

*Method of Inversion.*

25 cc. water, 1 cc. concentrated hydrochloric acid, and 10 cc. of the 10 per cent. sugar solution are placed in a 100 cc. flask. The whole is raised to 65–66°C. in a water-bath and maintained constant at this temperature for 20 minutes, after which it is cooled and 2.5 cc. 4N NaOH added

to neutralise the acid; the contents are now diluted to 100 cc., well shaken, and the copper reduction determined on 20 cc. (= 0.2 gm. original sugar) by the Brown, Morris and Millar method. This method should also be used for the other copper reduction required for this determination of sucrose.

CuO due to invert sugar from sucrose  
= total CuO after inversion - CuO due to invert sugar, etc.



$$\text{Per cent sucrose} = 500 \times \frac{352}{360} \times \text{invert sugar in 0.2 gm.}$$

## 2. Invert Sugar.

This is met with commercially in the form of very stiff pastes which also contain a smaller or larger amount of uninverted sucrose.

(1) The invert sugar is determined by the Brown, Morris and Millar method given under "Cane Sugar."

10 cc. of the 10 per cent. solution of invert sugar is diluted to 50 cc.; of this 10 cc. (= 0.2 gm.) are taken for the Cu reduction.

The CuO due to non-sugar substances must be determined and allowed for before stating the percentage of invert sugar in the sample.

(2) The sucrose is determined by any of the inversion methods given under "Cane Sugar."

For some purposes it is desired to know the actual amount of lævulose and dextrose in the sample; the amounts of these two sugars are not as a rule equal, the lævulose is usually several per cent (5-6) lower than dextrose; this is due to the comparative ease with which lævulose is destroyed by acid during the acid inversion process used in manufacture.

### Determination of Dextrose and Lævulose in Invert Sugars.

The following are required:—

1. The CuO (corrected for non-sugars) produced by 100 gm. of the sample. This is calculated from the CuO produced by 0.2 gm. of the sample, already ascertained in the determination of invert sugar in (1).
2. The rotation in 2 dm. tube (circular degrees), on a 10 per cent. solution.
3. The percentage of sucrose in the sample.
4. The rotation in 2 dm. tube (on solution equivalent to original 10 per cent. solution) after fermentation = reading due to non-sugars.



If  $W$  = weight of Cu reduced by 0.2 grm. sample.

$W_n$  = weight of Cu reduced by non-sugars in 0.2 grm. sample.

$C$  = weight of sucrose in 100 cc. 10 per cent. solution.

$R$  = reading in 2 dm. tube on 10 per cent. solution.

$R_n$  = reading in 2 dm. tube on 10 per cent. solution after fermentation.

Cu reduced by the dextrose and lævulose in 100 grm. of the sample =  $500 (W - W_n)$ .

$$[\alpha]_D = \frac{\alpha \times 100}{c \times l} \quad [\alpha]_D = \text{specific rotatory power (S.R.P.)}$$

$\alpha$  = reading in circular degrees in a tube  $l$  dm. long on a solution containing  $c$  grm. per 100 cc.

$C$  grm. sucrose in 100 cc. 10 per cent. solution of sample gives a reading of  $\alpha$  in 2 dm. tube.

$$66.5 = \frac{\alpha \times 100}{C \times 2} \quad \text{and} \quad \alpha = \frac{66.5 \times C \times 2}{100} = 1.33 C.$$

Reading due to dextrose and lævulose in 2 dm. tube 10 per cent. solution =  $R - R_n + 1.33 C$

The S.R.P. or  $[\alpha]_D$  of the sample due to dextrose and lævulose is given by

$$\frac{(R - R_n + 1.33 C) 100}{2 \times 10}.$$

On referring to Brown, Morris and Millar's table, the gram value of dextrose and lævulose with a reduction of  $R$  grams of Cu is found.

If  $G_D$  = the gram value of dextrose,

$G_L$  = the gram value of lævulose;

$D$  = the percentage of dextrose in the sample,

$L$  = the percentage of lævulose in the sample;

then  $G_D D + G_L L = 500 (W - W_n)$ ,

$$\text{and } 52.8 D + (-92.0 L) = 100 \times \frac{(R - R_n + 1.33 C) 100}{2 \times 10}.$$

### 3. Starch Sugar or Glucose.

This is prepared commercially by the acid hydrolysis of starch, and consists essentially of dextrose generally containing a small amount of maltose and dextrin.

Determinations required :

1.  $R_s$  = Cu reduction on 0.2 grm.

2.  $R_n$  = Cu reduction on 0.2 grm. after fermentation, determined on 1.25 grm. and calculated to 0.2 grm.

3.  $O_s$  = Rotation in 2 dm. tube on 10 per cent. solution.

4.  $O_n$  = Rotation in 2 dm. tube on 10 per cent. solution after fermentation; this reading is due to dextrin and non-sugar substances.



$G_D$  = the gram value of dextrose with a reduction of  $R_s$  for which the table of Brown, Morris and Millar is used.

$G_M$  = the gram value of maltose with a reduction of  $R_s$ , obtained from the following table of Brown, Morris and Millar.

$D$  = the percentage of dextrose in the sample.

$M$  = the percentage of maltose in the sample.

$$(1) \quad G_D D + G_M M = 500 (R_s - R_n)$$

$$\text{and } (2) \quad 52.8 D + 138.0 M = \frac{100 \times (O_s - O_n) \times 100}{2 \times 10}$$

TABLE SHOWING THE RELATION BETWEEN Cu, CuO. AND MALTOSE. (From Brown, Morris, and Millar. *J.C.S.*, 1897, 71, 100.)

| Maltose<br>gram. | Cu<br>gram. | Cu equivt.   |                        | Maltose<br>gram. | Cu<br>gram. | Cu equivt.   |                        |
|------------------|-------------|--------------|------------------------|------------------|-------------|--------------|------------------------|
|                  |             | CuO<br>gram. | to 1 gram.<br>Maltose. |                  |             | CuO<br>gram. | to 1 gram.<br>Maltose. |
| .070             | .0772       | .0966        | 1.1029                 | .190             | .2072       | .2593        | 1.0953                 |
| .075             | .0826       | .1034        | 1.1026                 | .195             | .2126       | .2661        | 1.0949                 |
| .080             | .0880       | .1102        | 1.1023                 | .200             | .2180       | .2729        | 1.0946                 |
| .085             | .0934       | .1169        | 1.1020                 | .205             | .2234       | .2797        | 1.0943                 |
| .090             | .0988       | .1237        | 1.1017                 | .210             | .2288       | .2865        | 1.0940                 |
| .095             | .1042       | .1305        | 1.1013                 | .215             | .2342       | .2933        | 1.0937                 |
| .100             | .1097       | .1373        | 1.1010                 | .220             | .2397       | .3000        | 1.0933                 |
| .105             | .1151       | .1441        | 1.1007                 | .225             | .2451       | .3068        | 1.0930                 |
| .110             | .1205       | .1509        | 1.1004                 | .230             | .2505       | .3136        | 1.0927                 |
| .115             | .1259       | .1576        | 1.1001                 | .235             | .2559       | .3203        | 1.0924                 |
| .120             | .1313       | .1644        | 1.0997                 | .240             | .2613       | .3272        | 1.0921                 |
| .125             | .1367       | .1712        | 1.0994                 | .245             | .2667       | .3340        | 1.0917                 |
| .130             | .1422       | .1779        | 1.0991                 | .250             | .2722       | .3407        | 1.0914                 |
| .135             | .1476       | .1848        | 1.0988                 | .255             | .2776       | .3475        | 1.0911                 |
| .140             | .1530       | .1916        | 1.0985                 | .260             | .2830       | .3543        | 1.0908                 |
| .145             | .1584       | .1983        | 1.0981                 | .265             | .2884       | .3610        | 1.0905                 |
| .150             | .1634       | .2051        | 1.0978                 | .270             | .2938       | .3678        | 1.0901                 |
| .155             | .1692       | .2119        | 1.0975                 | .275             | .2992       | .3747        | 1.0898                 |
| .160             | .1747       | .2186        | 1.0972                 | .280             | .3047       | .3814        | 1.0895                 |
| .165             | .1801       | .2254        | 1.0969                 | .285             | .3101       | .3882        | 1.0892                 |
| .170             | .1855       | .2323        | 1.0965                 | .290             | .3155       | .3950        | 1.0889                 |
| .175             | .1909       | .2490        | 1.0962                 | .295             | .3209       | .4017        | 1.0885                 |
| .180             | .1963       | .2458        | 1.0959                 | .300             | .3264       | .4085        | 1.0882                 |
| .185             | .2017       | .2526        | 1.0956                 | .305             | .3318       | .4154        | 1.0879                 |

## Additional Determinations for all Commercial Sugars.

(1) *Ash*. Determined on 5 grm. of the sample by careful charring in a platinum dish and finally igniting to a white ash.

(2) *Moisture*. Carbohydrates generally are extremely difficult to obtain anhydrous, special drying apparatus, including  $P_2O_5$ , being required; for technical work where a number of such determinations are necessary, this method of drying is excluded. The conventional method is as follows:—

The Sp. Gr. of a 10 per cent. solution (i.e., 10 grm. in 100 cc. solution) is determined with the Sp. Gr. bottle or Sprengel tube and referred to water=1000. Excess Sp. Gr. over 1000 divided by 3.86 gives the dry solids in 100 cc. solution (=10 grm. of sample), and these multiplied by 10 the total dry solids per cent. on the sample (= T.S.).

$$100 - T.S. = \text{per cent. moisture.}$$

The ash, however, introduces an error, for while 1 grm. of sugar in 100 cc. solution gives a Sp. Gr. of 1003.86, 1 grm. of ash in 100 cc. gives a Sp. Gr. of 1008.0, i.e. about twice that of sugar; therefore, to correct for the ash, the per cent. ash is subtracted from the solids first found, which leaves the real T.S. and hence the moisture.

(3) *Proteins*. By the ordinary Kjeldahl method on 4–5 grm. of the sample. N is calculated to protein by the factor 6.25 or 6.3, according to different investigators.

The proteins in sugars are usually only small in amount, and it is absolutely essential to do a blank with each fresh stock of reagents.

The methods detailed apply to technical products which seldom, with the exception of the high grade cane sugars, consist of one sugar or even sugar and water alone; such methods are naturally complicated, but if the product under investigation is known to consist of one sugar and water or to contain only one sugar together with other inactive bodies then the methods may be very much simplified, and in such cases either the Sp.Gr., the S.R.P., or reducing power of the product may be sufficient.

The sum of the total sugars, moisture, ash, and protein, deducted from 100 gives the *Unfermentable Matter* per cent., returned as such without reference to its nature.

## SPECIFIC ROTATORY POWERS OF SUGARS

p = grm. in 100 grm. solution.

C = grm. in 100 cc.

| Sugar.    | Authority.          | $[\alpha]_D$ | °C.  | Concen-<br>tration. | Solution<br>Factor. |
|-----------|---------------------|--------------|------|---------------------|---------------------|
| Lævulose. | —                   | 92.25        | 20   | p=10                | —                   |
|           | Ling, Eynon, & Lane | - 93.83      | 18.5 | C=10                | —                   |
|           | Brown.              | - 92.0       | 20   | C=10                | See next<br>table   |
|           | Briant.             | - 92.0       | 20   | C=10                | 3.86                |
| Maltose.  | Brown, Morris,      |              |      |                     |                     |
|           | and Milla           | +138.0       | 20   | C=10                | 3.86                |
|           | Ling, Eynon, & Lane | +137.8       | 17.5 | C= 5.7              | —                   |
|           | —                   | +136.8       | 20   | C=10                | —                   |
| Invert.   | —                   | - 27.9       | 0    | C=17.2              | —                   |
|           | —                   | 20.05        | 15   | —                   | —                   |
|           | —                   | 0            | 87.2 | —                   | —                   |
| Lactose   | —                   | 52.5         | 20   | p= 5.7              | —                   |
| Dextrose. | —                   | 51.7         | 15°  | C= 3                | —                   |
|           | Brown.              | 52.8         | 20   | C=10                | See next<br>table   |
|           | Briant              | 51.7         | —    | C=10                | 3.86                |
|           | Ling, Eynon & Lane  | 52.72        | 17°  | C=10                | —                   |
| Sucrose.  | —                   | 66.6         | 20   | p= 4.18             | —                   |
|           | Brown.              | 66.6         | 20   | C=10                | See next<br>table   |
|           | Briant              | 66.6         | —    | C=10                | 3.86                |

Tuchschmid gives the following for the S.R.P. of invert sugar at any temperature :

$$[\alpha]_D = (27.9^\circ - 0.32t).$$

$[\alpha]_y$  is the S.R.P. for the "medium yellow" of the spectrum, and is equal to  $[\alpha]_D \times 1.111$ .

One form of Schmidt and Haensch half-shadow polarimeter has a straight scale of 100 divisions. The reading 100 is given in 2 dm. tube by a solution containing 26.048 grm. of sucrose in 100 cc. solution at 17.5° C., i.e., when this amount of the sugar sample is dissolved and made up to 100 cc. the reading gives directly the per cent. sucrose in the sample, just as in the Soleil-Ventzke-Scheibler polarimeter.

Each scale division = 0.3459 of a degree Laurent (circular degrees) for all ordinary sugars other than sucrose, and = 0.3469 of a degree for sucrose.

To convert divisions into degrees  $[\alpha]_D$  multiply by 0.3854 for sucrose, and by 0.3843 for other sugars.

In cases where the solution is too deep in colour for direct observation the colour may usually be precipitated by adding a few drops of basic lead acetate or of alumina cream before diluting the solution to the mark, avoiding unnecessary excess, which tends to carry down sugar; generally 5 drops per 50 cc. of 10 per cent. solution are sufficient. If this treatment fails, animal charcoal may be employed.

### *Solution Factors of Sugars.*

The use of these has been described under "Moisture in sugar." However one factor is not absolutely correct for all sugars, nor is it correct for one sugar at all concentrations, but notwithstanding this, the factor 3.86 is used by general convention for all sugars for technical purposes.

In case the correct solution factor is required for any specific sugar at a certain concentration, it may be obtained from a graph given by Brown, Morris and Millar, (*J.C.S.*, 1897, 71, 72) from which the following table is compiled:—

#### DIVISORS FOR SUGARS AT VARIOUS DENSITIES.

| Sp. Gr.<br>at 15.5°C. | Dextrose. | Sucrose. | Invert<br>Sugar. | Lævulose. | Maltose. |
|-----------------------|-----------|----------|------------------|-----------|----------|
| 1010                  | 3.845     | 3.869    | 3.895            | 3.940     | 3.938    |
| 20                    | 3.841     | 3.867    | 3.892            | 3.932     | 3.934    |
| 30                    | 3.837     | 3.865    | 3.890            | 3.925     | 3.929    |
| 40                    | 3.832     | 3.863    | 3.887            | 3.918     | 3.924    |
| 50                    | 3.827     | 3.860    | 3.884            | 3.910     | 3.919    |
| 60                    | 3.821     | 3.857    | 3.881            | 3.903     | 3.913    |
| 70                    | 3.814     | 3.854    | 3.878            | 3.895     | 3.907    |
| 80                    | 3.807     | 3.850    | 3.875            | 3.887     | 3.902    |
| 90                    | 3.799     | 3.847    | 3.872            | 3.880     | 3.895    |
| 1100                  | 3.791     | 3.842    | 3.869            | 3.871     | 3.889    |
| 10                    | —         | —        | 3.865            | —         | 3.883    |
| 20                    | —         | —        | 3.862            | —         | 3.876    |
| 30                    | —         | —        | 3.858            | —         | 3.869    |
| 40                    | —         | —        | 3.854            | —         | 3.862    |

# Conversion of Saccharometer Readings to Specific Gravities (Mateczek and Scheibler).

Balling's Saccharometer, improved by Brix, gives directly

°Brix = Percentage of sugar.

The following table refers to Sp. Gr. of solution at 17.5°C compared to water at 17.5°C. = 1.

| °Brix. | Sp. Gr. | °Brix. | Sp. Gr. | °Brix. | Sp. Gr. |
|--------|---------|--------|---------|--------|---------|
| 0.0    | 1.00000 | 8.4    | 1.03352 | 16.8   | 1.06914 |
| 0.2    | 0077    | 8.6    | 3434    | 17.0   | 7002    |
| 0.4    | 0155    | 8.8    | 3517    | 17.2   | 7090    |
| 0.6    | 0232    | 9.0    | 3599    | 17.4   | 7177    |
| 0.8    | 0310    | 9.2    | 3682    | 17.6   | 7265    |
| 1.0    | 0388    | 9.4    | 3765    | 17.8   | 7353    |
| 1.2    | 0466    | 9.6    | 3843    | 18.0   | 7441    |
| 1.4    | 0544    | 9.8    | 3931    | 18.2   | 7530    |
| 1.6    | 0622    | 10.0   | 4014    | 18.4   | 7618    |
| 1.8    | 0701    | 10.2   | 4097    | 18.6   | 7706    |
| 2.0    | 0779    | 10.4   | 4180    | 18.8   | 7795    |
| 2.2    | 0858    | 10.6   | 4264    | 19.0   | 7884    |
| 2.4    | 0936    | 10.8   | 4348    | 19.2   | 7973    |
| 2.6    | 1015    | 11.0   | 4431    | 19.4   | 8062    |
| 2.8    | 1094    | 11.2   | 4515    | 19.6   | 8151    |
| 3.0    | 1173    | 11.4   | 4599    | 19.8   | 8240    |
| 3.2    | 1252    | 11.6   | 4683    | 20.0   | 8329    |
| 3.4    | 1332    | 11.8   | 4768    | 20.2   | 8419    |
| 3.6    | 1411    | 12.0   | 4852    | 20.4   | 8509    |
| 3.8    | 1491    | 12.2   | 4937    | 20.6   | 8599    |
| 4.0    | 1570    | 12.4   | 5021    | 20.8   | 8688    |
| 4.2    | 1650    | 12.6   | 5106    | 21.0   | 8778    |
| 4.4    | 1730    | 12.8   | 5191    | 21.2   | 8869    |
| 4.6    | 1810    | 13.0   | 5276    | 21.4   | 8959    |
| 4.8    | 1890    | 13.2   | 5361    | 21.6   | 9049    |
| 5.0    | 1970    | 13.4   | 5446    | 21.8   | 9140    |
| 5.2    | 2051    | 13.6   | 5532    | 22.0   | 9231    |
| 5.4    | 2131    | 13.8   | 5617    | 22.2   | 9321    |
| 5.6    | 2211    | 14.0   | 5703    | 22.4   | 9412    |
| 5.8    | 2292    | 14.2   | 5789    | 22.6   | 9503    |
| 6.0    | 2373    | 14.4   | 5874    | 22.8   | 9595    |
| 6.2    | 2454    | 14.6   | 5960    | 23.0   | 9686    |
| 6.4    | 2535    | 14.8   | 6047    | 23.2   | 9777    |
| 6.6    | 2616    | 15.0   | 6133    | 23.4   | 9869    |
| 6.8    | 2697    | 15.2   | 6219    | 23.6   | 9961    |
| 7.0    | 2779    | 15.4   | 6306    | 23.8   | 1.10053 |
| 7.2    | 2860    | 15.6   | 6392    | 24.0   | 0145    |
| 7.4    | 2942    | 15.8   | 6479    | 24.2   | 0237    |
| 7.6    | 3024    | 16.0   | 6566    | 24.4   | 0329    |
| 7.8    | 3105    | 16.2   | 6653    | 24.6   | 0421    |
| 8.0    | 3187    | 16.4   | 6740    | 24.8   | 0514    |
| 8.2    | 3270    | 16.6   | 6827    | 25.0   | 0607    |

| ° Brix. | Sp. Gr. | ° Brix. | Sp. Gr. | ° Brix. | Sp. Gr. |
|---------|---------|---------|---------|---------|---------|
| 25.2    | 1.10700 | 34.4    | 1.15113 | 43.6    | 1.19822 |
| 25.4    | 0793    | 34.6    | 5213    | 43.8    | 9927    |
| 25.6    | 0886    | 34.8    | 5312    | 44.0    | 1.20033 |
| 25.8    | 0979    | 35.0    | 5411    | 44.2    | 0139    |
| 26.0    | 1072    | 35.2    | 5511    | 44.4    | 0245    |
| 26.2    | 1166    | 35.4    | 5611    | 44.6    | 0352    |
| 26.4    | 1259    | 35.6    | 5710    | 44.8    | 0458    |
| 26.6    | 1353    | 35.8    | 5810    | 45.0    | 0565    |
| 26.8    | 1447    | 36.0    | 5911    | 45.2    | 0672    |
| 27.0    | 1541    | 36.2    | 6011    | 45.4    | 0779    |
| 27.2    | 1635    | 36.4    | 6111    | 45.6    | 0886    |
| 27.4    | 1729    | 36.6    | 6212    | 45.8    | 0993    |
| 27.6    | 1824    | 36.8    | 6313    | 46.0    | 1100    |
| 27.8    | 1918    | 37.0    | 6413    | 46.2    | 1208    |
| 28.0    | 2013    | 37.2    | 6514    | 46.4    | 1315    |
| 28.2    | 2107    | 37.4    | 6616    | 46.6    | 1423    |
| 28.4    | 2202    | 37.6    | 6717    | 46.8    | 1531    |
| 28.6    | 2297    | 37.8    | 6818    | 47.0    | 1639    |
| 28.8    | 2393    | 38.0    | 6920    | 47.2    | 1747    |
| 29.0    | 2488    | 38.2    | 7022    | 47.4    | 1856    |
| 29.2    | 2583    | 38.4    | 7123    | 47.6    | 1964    |
| 29.4    | 2679    | 38.6    | 7225    | 47.8    | 2073    |
| 29.6    | 2775    | 38.8    | 7327    | 48.0    | 2182    |
| 29.8    | 2871    | 39.0    | 7430    | 48.2    | 2291    |
| 30.0    | 2967    | 39.2    | 7532    | 48.4    | 2400    |
| 30.2    | 3063    | 39.4    | 7635    | 48.6    | 2509    |
| 30.4    | 3159    | 39.6    | 7737    | 48.8    | 2619    |
| 30.6    | 3255    | 39.8    | 7840    | 49.0    | 2728    |
| 30.8    | 3352    | 40.0    | 7943    | 49.2    | 2838    |
| 31.0    | 3449    | 40.2    | 8046    | 49.4    | 2948    |
| 31.2    | 3545    | 40.4    | 8150    | 49.6    | 3058    |
| 31.4    | 3642    | 40.6    | 8253    | 49.8    | 3168    |
| 31.6    | 3740    | 40.8    | 8357    | 50.0    | 3278    |
| 31.8    | 3837    | 41.0    | 8460    | 50.2    | 3389    |
| 32.0    | 3934    | 41.2    | 8564    | 50.4    | 3499    |
| 32.2    | 4032    | 41.4    | 8668    | 50.6    | 3610    |
| 32.4    | 4129    | 41.6    | 8772    | 50.8    | 3721    |
| 32.6    | 4227    | 41.8    | 8877    | 51.0    | 3832    |
| 32.8    | 4325    | 42.0    | 8981    | 51.2    | 3943    |
| 33.0    | 4423    | 42.2    | 9086    | 51.4    | 4055    |
| 33.2    | 4521    | 42.4    | 9190    | 51.6    | 4166    |
| 33.4    | 4620    | 42.6    | 9295    | 51.8    | 4278    |
| 33.6    | 4718    | 42.8    | 9400    | 52.0    | 4390    |
| 33.8    | 4817    | 43.0    | 9505    | 52.2    | 4502    |
| 34.0    | 4915    | 43.2    | 9611    | 52.4    | 4614    |
| 34.2    | 5014    | 43.4    | 9716    | 52.6    | 4726    |

| °Brix. | Sp. Gr. | °Brix. | Sp. Gr. | °Brix. | Sp. Gr. |
|--------|---------|--------|---------|--------|---------|
| 52.8   | 1.24839 | 62.0   | 1.30177 | 71.2   | 1.35847 |
| 53.0   | 4951    | 62.2   | 0297    | 71.4   | 5974    |
| 53.2   | 5064    | 62.4   | 0416    | 71.6   | 6101    |
| 53.4   | 5177    | 62.6   | 0536    | 71.8   | 6228    |
| 53.6   | 5290    | 62.8   | 0657    | 72.0   | 6355    |
| 53.8   | 5403    | 63.0   | 0777    | 72.2   | 6483    |
| 54.0   | 5517    | 63.2   | 0897    | 72.4   | 6611    |
| 54.2   | 5630    | 63.4   | 1018    | 72.6   | 6739    |
| 54.4   | 5744    | 63.6   | 1139    | 72.8   | 6867    |
| 54.6   | 5857    | 63.8   | 1260    | 73.0   | 6995    |
| 54.8   | 5971    | 64.0   | 1381    | 73.2   | 7124    |
| 55.0   | 6086    | 64.2   | 1502    | 73.4   | 7252    |
| 55.2   | 6200    | 64.4   | 1624    | 73.6   | 7381    |
| 55.4   | 6314    | 64.6   | 1745    | 73.8   | 7510    |
| 55.6   | 6429    | 64.8   | 1867    | 74.0   | 7639    |
| 55.8   | 6544    | 65.0   | 1989    | 74.2   | 7768    |
| 56.0   | 6658    | 65.2   | 2111    | 74.4   | 7898    |
| 56.2   | 6773    | 65.4   | 2233    | 74.6   | 8027    |
| 56.4   | 6889    | 65.6   | 2355    | 74.8   | 8157    |
| 56.6   | 7004    | 65.8   | 2478    | 75.0   | 8287    |
| 56.8   | 7120    | 66.0   | 2601    | 75.2   | 8417    |
| 57.0   | 7235    | 66.2   | 2724    | 75.4   | 8547    |
| 57.2   | 7351    | 66.4   | 2847    | 75.6   | 8677    |
| 57.4   | 7464    | 66.6   | 2970    | 75.8   | 8808    |
| 57.6   | 7583    | 66.8   | 3093    | 76.0   | 8939    |
| 57.8   | 7699    | 67.0   | 3217    | 76.2   | 9070    |
| 58.0   | 7816    | 67.2   | 3340    | 76.4   | 9201    |
| 58.2   | 7932    | 67.4   | 3464    | 76.6   | 9332    |
| 58.4   | 8049    | 67.6   | 3588    | 76.8   | 9463    |
| 58.6   | 8166    | 67.8   | 3712    | 77.0   | 9595    |
| 58.8   | 8283    | 68.0   | 3836    | 77.2   | 9726    |
| 59.0   | 8400    | 68.2   | 3961    | 77.4   | 9858    |
| 59.2   | 8518    | 68.4   | 4085    | 77.6   | 9990    |
| 59.4   | 8635    | 68.6   | 4210    | 77.8   | 1.40122 |
| 59.6   | 8753    | 68.8   | 4335    | 78.0   | 0254    |
| 59.8   | 8871    | 69.0   | 4460    | 78.2   | 0387    |
| 60.0   | 8989    | 69.2   | 4585    | 78.4   | 0520    |
| 60.2   | 9107    | 69.4   | 4711    | 78.6   | 0652    |
| 60.4   | 9225    | 69.6   | 4836    | 78.8   | 0785    |
| 60.6   | 9343    | 69.8   | 4962    | 79.0   | 0918    |
| 60.8   | 9462    | 70.0   | 5088    | 79.2   | 1052    |
| 61.0   | 9581    | 70.2   | 5214    | 79.4   | 1185    |
| 61.2   | 9700    | 70.4   | 5450    | 79.6   | 1318    |
| 61.4   | 9819    | 70.6   | 5466    | 79.8   | 1452    |
| 61.6   | 9938    | 70.8   | 5593    | 80.0   | 1586    |
| 61.8   | 1.30057 | 71.0   | 5720    | 80.2   | 1720    |



| °Brix. | Sp. Gr. | °Brix. | Sp. Gr. | °Brix. | Sp. Gr. |
|--------|---------|--------|---------|--------|---------|
| 80.4   | 1.41854 | 85.4   | 1.45262 | 90.4   | 1.48771 |
| 80.6   | 1989    | 85.6   | 5401    | 90.6   | 8913    |
| 80.8   | 2123    | 85.8   | 5539    | 90.8   | 9056    |
| 81.0   | 2258    | 86.0   | 5678    | 91.0   | 9199    |
| 81.2   | 2393    | 86.2   | 5817    | 91.2   | 9342    |
| 81.4   | 2528    | 86.4   | 5956    | 91.4   | 9485    |
| 81.6   | 2663    | 86.6   | 6095    | 91.6   | 9628    |
| 81.8   | 2798    | 86.8   | 6235    | 91.8   | 9771    |
| 82.0   | 2934    | 87.0   | 6374    | 92.0   | 9915    |
| 82.2   | 3070    | 87.2   | 6514    | 92.2   | 1.50058 |
| 82.4   | 3205    | 87.4   | 6654    | 92.4   | 0202    |
| 82.6   | 3341    | 87.6   | 6794    | 92.6   | 0346    |
| 82.8   | 3478    | 87.8   | 6934    | 92.8   | 0491    |
| 83.0   | 3614    | 88.0   | 7074    | 93.0   | 0635    |
| 83.2   | 3750    | 88.2   | 7215    | 93.2   | 0779    |
| 83.4   | 3887    | 88.4   | 7356    | 93.4   | 0924    |
| 83.6   | 4024    | 88.6   | 7496    | 93.6   | 1069    |
| 83.8   | 4161    | 88.8   | 7637    | 93.8   | 1214    |
| 84.0   | 4298    | 89.0   | 7778    | 94.0   | 1359    |
| 84.2   | 4435    | 89.2   | 7920    | 94.2   | 1504    |
| 84.4   | 4573    | 89.4   | 8061    | 94.4   | 1649    |
| 84.6   | 4710    | 89.6   | 8203    | 94.6   | 1795    |
| 84.8   | 4848    | 89.8   | 8345    | 94.8   | 1941    |
| 85.0   | 4986    | 90.0   | 8486    | 95.0   | 2087    |
| 85.2   | 5124    | 90.2   | 8629    |        |         |

### Conversion of Specific Gravities at 17.5°C to Saccharometer Degrees. (Balling).

Headings of column give fourth decimal figure of Sp. Gr.

° Balling = % Cane Sugar in the solution.

|       | 0     | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1.008 | 2.000 | 2.025 | 2.050 | 2.075 | 2.100 | 2.125 | 2.150 | 2.175 | 2.200 | 2.225 |
| 1.009 | 2.250 | 2.275 | 2.300 | 2.325 | 2.350 | 2.375 | 2.400 | 2.425 | 2.450 | 2.475 |
| 1.010 | 2.500 | 2.525 | 2.550 | 2.575 | 2.600 | 2.625 | 2.650 | 2.675 | 2.700 | 2.725 |
| 1.011 | 2.750 | 2.775 | 2.800 | 2.825 | 2.850 | 2.875 | 2.900 | 2.925 | 2.950 | 2.975 |
| 1.012 | 3.000 | 3.025 | 3.050 | 3.075 | 3.100 | 3.125 | 3.150 | 3.175 | 3.200 | 3.225 |
| 1.013 | 3.250 | 3.275 | 3.300 | 3.325 | 3.350 | 3.375 | 3.400 | 3.425 | 3.450 | 3.475 |
| 1.014 | 3.500 | 3.525 | 3.550 | 3.575 | 3.600 | 3.625 | 3.650 | 3.675 | 3.700 | 3.725 |
| 1.015 | 3.750 | 3.775 | 3.800 | 3.825 | 3.850 | 3.875 | 3.900 | 3.925 | 3.950 | 3.975 |
| 1.016 | 4.000 | 4.025 | 4.050 | 4.075 | 4.100 | 4.125 | 4.150 | 4.175 | 4.200 | 4.225 |
| 1.017 | 4.250 | 4.275 | 4.300 | 4.325 | 4.350 | 4.375 | 4.400 | 4.425 | 4.450 | 4.475 |
| 1.018 | 4.500 | 4.525 | 4.550 | 4.575 | 4.600 | 4.625 | 4.650 | 4.675 | 4.700 | 4.725 |
| 1.019 | 4.750 | 4.775 | 4.800 | 4.825 | 4.850 | 4.875 | 4.900 | 4.925 | 4.950 | 4.975 |

|       | 0      | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 1.020 | 5.000  | 5.025  | 5.050  | 5.075  | 5.100  | 5.125  | 5.150  | 5.175  | 5.200  | 5.225  |
| 1.021 | 5.250  | 5.275  | 5.300  | 5.325  | 5.350  | 5.375  | 5.400  | 5.425  | 5.450  | 5.475  |
| 1.022 | 5.500  | 5.525  | 5.550  | 5.575  | 5.600  | 5.625  | 5.650  | 5.675  | 5.700  | 5.725  |
| 1.023 | 5.750  | 5.775  | 5.800  | 5.825  | 5.850  | 5.875  | 5.900  | 5.925  | 5.950  | 5.975  |
| 1.024 | 6.000  | 6.024  | 6.048  | 6.073  | 6.097  | 6.122  | 6.146  | 6.170  | 6.195  | 6.219  |
| 1.025 | 6.244  | 6.268  | 6.292  | 6.316  | 6.341  | 6.365  | 6.389  | 6.413  | 6.438  | 6.463  |
| 1.026 | 6.488  | 6.512  | 6.536  | 6.560  | 6.584  | 6.609  | 6.633  | 6.657  | 6.681  | 6.706  |
| 1.027 | 6.731  | 6.756  | 6.780  | 6.804  | 6.828  | 6.853  | 6.877  | 6.901  | 6.925  | 6.950  |
| 1.028 | 6.975  | 7.000  | 7.024  | 7.048  | 7.073  | 7.097  | 7.122  | 7.146  | 7.170  | 7.195  |
| 1.029 | 7.219  | 7.244  | 7.268  | 7.292  | 7.316  | 7.341  | 7.365  | 7.389  | 7.413  | 7.438  |
| 1.030 | 7.463  | 7.488  | 7.512  | 7.536  | 7.560  | 7.584  | 7.609  | 7.633  | 7.657  | 7.681  |
| 1.031 | 7.706  | 7.731  | 7.756  | 7.780  | 7.804  | 7.828  | 7.853  | 7.877  | 7.901  | 7.925  |
| 1.032 | 7.950  | 7.975  | 8.000  | 8.024  | 8.048  | 8.073  | 8.097  | 8.122  | 8.146  | 8.170  |
| 1.033 | 8.195  | 8.219  | 8.244  | 8.268  | 8.292  | 8.316  | 8.341  | 8.365  | 8.389  | 8.413  |
| 1.034 | 8.438  | 8.463  | 8.488  | 8.512  | 8.536  | 8.560  | 8.584  | 8.609  | 8.633  | 8.657  |
| 1.035 | 8.681  | 8.706  | 8.731  | 8.756  | 8.780  | 8.804  | 8.828  | 8.853  | 8.877  | 8.901  |
| 1.036 | 8.925  | 8.950  | 8.975  | 9.000  | 9.024  | 9.048  | 9.073  | 9.097  | 9.122  | 9.146  |
| 1.037 | 9.170  | 9.195  | 9.219  | 9.244  | 9.268  | 9.292  | 9.316  | 9.341  | 9.365  | 9.389  |
| 1.038 | 9.413  | 9.438  | 9.463  | 9.488  | 9.512  | 9.536  | 9.560  | 9.584  | 9.609  | 9.633  |
| 1.039 | 9.657  | 9.681  | 9.706  | 9.731  | 9.756  | 9.780  | 9.804  | 9.828  | 9.853  | 9.877  |
| 1.040 | 9.901  | 9.925  | 9.950  | 9.975  | 10.000 | 10.023 | 10.047 | 10.071 | 10.095 | 10.119 |
| 1.041 | 10.142 | 10.166 | 10.190 | 10.214 | 10.238 | 10.261 | 10.285 | 10.309 | 10.333 | 10.357 |
| 1.042 | 10.381 | 10.404 | 10.428 | 10.452 | 10.476 | 10.500 | 10.523 | 10.547 | 10.571 | 10.595 |
| 1.043 | 10.618 | 10.642 | 10.666 | 10.690 | 10.714 | 10.738 | 10.761 | 10.785 | 10.809 | 10.833 |
| 1.044 | 10.857 | 10.881 | 10.904 | 10.928 | 10.952 | 10.976 | 11.000 | 11.023 | 11.047 | 11.071 |
| 1.045 | 11.095 | 11.119 | 11.142 | 11.166 | 11.190 | 11.214 | 11.238 | 11.261 | 11.285 | 11.309 |
| 1.046 | 11.333 | 11.357 | 11.381 | 11.404 | 11.428 | 11.452 | 11.476 | 11.500 | 11.523 | 11.547 |
| 1.047 | 11.571 | 11.595 | 11.619 | 11.642 | 11.666 | 11.690 | 11.714 | 11.738 | 11.761 | 11.785 |
| 1.048 | 11.809 | 11.833 | 11.857 | 11.881 | 11.904 | 11.928 | 11.952 | 11.976 | 12.000 | 12.023 |
| 1.049 | 12.047 | 12.071 | 12.095 | 12.119 | 12.142 | 12.166 | 12.190 | 12.214 | 12.238 | 12.261 |
| 1.050 | 12.285 | 12.309 | 12.333 | 12.357 | 12.381 | 12.404 | 12.428 | 12.452 | 12.476 | 12.500 |
| 1.051 | 12.523 | 12.547 | 12.571 | 12.595 | 12.619 | 12.642 | 12.666 | 12.690 | 12.714 | 12.738 |
| 1.052 | 12.761 | 12.785 | 12.809 | 12.833 | 12.857 | 12.881 | 12.904 | 12.928 | 12.952 | 12.976 |
| 1.053 | 13.000 | 13.023 | 13.047 | 13.071 | 13.095 | 13.119 | 13.142 | 13.166 | 13.190 | 13.214 |
| 1.054 | 13.238 | 13.261 | 13.285 | 13.309 | 13.333 | 13.357 | 13.381 | 13.404 | 13.428 | 13.452 |
| 1.055 | 13.476 | 13.500 | 13.523 | 13.547 | 13.571 | 13.595 | 13.619 | 13.642 | 13.666 | 13.690 |
| 1.056 | 13.714 | 13.738 | 13.761 | 13.785 | 13.809 | 13.833 | 13.857 | 13.881 | 13.904 | 13.928 |
| 1.057 | 13.952 | 13.976 | 14.000 | 14.023 | 14.047 | 14.071 | 14.095 | 14.119 | 14.142 | 14.166 |
| 1.058 | 14.190 | 14.214 | 14.238 | 14.261 | 14.285 | 14.309 | 14.333 | 14.357 | 14.381 | 14.404 |
| 1.059 | 14.428 | 14.452 | 14.476 | 14.500 | 14.523 | 14.547 | 14.571 | 14.595 | 14.619 | 14.642 |
| 1.060 | 14.666 | 14.690 | 14.714 | 14.738 | 14.761 | 14.785 | 14.809 | 14.833 | 14.857 | 14.881 |
| 1.061 | 14.904 | 14.928 | 14.952 | 14.976 | 15.000 | 15.023 | 15.046 | 15.070 | 15.093 | 15.116 |
| 1.062 | 15.139 | 15.162 | 15.186 | 15.209 | 15.232 | 15.255 | 15.278 | 15.302 | 15.325 | 15.348 |
| 1.063 | 15.371 | 15.395 | 15.418 | 15.441 | 15.464 | 15.488 | 15.511 | 15.534 | 15.557 | 15.581 |
| 1.064 | 15.604 | 15.627 | 15.650 | 15.674 | 15.697 | 15.721 | 15.744 | 15.767 | 15.790 | 15.814 |
| 1.065 | 15.837 | 15.860 | 15.883 | 15.907 | 15.930 | 15.953 | 15.976 | 16.000 | 16.023 | 16.046 |

|       | 0      | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 1.666 | 16.070 | 16.093 | 16.116 | 16.139 | 16.162 | 16.186 | 16.209 | 16.232 | 16.255 | 16.273 |
| 1.667 | 16.302 | 16.325 | 16.348 | 16.371 | 16.395 | 16.418 | 16.441 | 16.464 | 16.488 | 16.511 |
| 1.668 | 16.534 | 16.557 | 16.581 | 16.604 | 16.627 | 16.650 | 16.674 | 16.697 | 16.721 | 16.744 |
| 1.669 | 16.767 | 16.790 | 16.814 | 16.837 | 16.860 | 16.883 | 16.907 | 16.930 | 16.953 | 16.976 |
| 1.070 | 17.000 | 17.022 | 17.045 | 17.067 | 17.090 | 17.113 | 17.136 | 17.158 | 17.181 | 17.204 |
| 1.071 | 17.227 | 17.250 | 17.272 | 17.295 | 17.318 | 17.340 | 17.363 | 17.386 | 17.409 | 17.431 |
| 1.072 | 17.454 | 17.477 | 17.500 | 17.522 | 17.545 | 17.568 | 17.590 | 17.613 | 17.636 | 17.659 |
| 1.073 | 17.681 | 17.704 | 17.727 | 17.750 | 17.772 | 17.795 | 17.818 | 17.841 | 17.863 | 17.886 |
| 1.074 | 17.909 | 17.931 | 17.954 | 17.977 | 18.000 | 18.022 | 18.045 | 18.067 | 18.090 | 18.113 |
| 1.075 | 18.137 | 18.158 | 18.181 | 18.204 | 18.227 | 18.250 | 18.272 | 18.295 | 18.318 | 18.340 |
| 1.076 | 18.363 | 18.386 | 18.409 | 18.431 | 18.454 | 18.477 | 18.500 | 18.522 | 18.545 | 18.569 |
| 1.077 | 18.590 | 18.613 | 18.636 | 18.659 | 18.681 | 18.704 | 18.724 | 18.750 | 18.772 | 18.795 |
| 1.078 | 18.818 | 18.841 | 18.863 | 18.886 | 18.909 | 18.931 | 18.954 | 18.977 | 19.000 | 19.022 |
| 1.079 | 19.045 | 19.067 | 19.090 | 19.113 | 19.136 | 19.158 | 19.181 | 19.204 | 19.227 | 19.250 |

## Correction of Saccharometer Readings to 17.5°C. (Sachs).

| °C. | Degrees Brix of Solution |      |      |      |      |      |      |      |      |      |      |      |      |
|-----|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|
|     | 0                        | 5    | 10   | 15   | 20   | 25   | 30   | 35   | 40   | 50   | 60   | 70   | 75   |
| 0   | -0.27                    | 0.30 | 0.41 | 0.52 | 0.62 | 0.72 | 0.82 | 0.92 | 0.98 | 1.11 | 1.22 | 1.25 | 1.29 |
| 5   | 0.23                     | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.65 | 0.72 | 0.75 | 0.80 | 0.88 | 0.91 | 0.94 |
| 10  | 0.20                     | 0.26 | 0.29 | 0.33 | 0.36 | 0.39 | 0.42 | 0.45 | 0.48 | 0.50 | 0.54 | 0.58 | 0.61 |
| 11  | 0.18                     | 0.23 | 0.26 | 0.28 | 0.31 | 0.34 | 0.36 | 0.39 | 0.41 | 0.43 | 0.47 | 0.50 | 0.53 |
| 12  | 0.16                     | 0.20 | 0.22 | 0.24 | 0.26 | 0.29 | 0.31 | 0.33 | 0.34 | 0.36 | 0.40 | 0.42 | 0.46 |
| 13  | 0.14                     | 0.18 | 0.19 | 0.21 | 0.22 | 0.24 | 0.26 | 0.27 | 0.28 | 0.29 | 0.33 | 0.35 | 0.39 |
| 14  | 0.12                     | 0.15 | 0.16 | 0.17 | 0.18 | 0.19 | 0.21 | 0.22 | 0.22 | 0.23 | 0.26 | 0.28 | 0.32 |
| 15  | 0.09                     | 0.11 | 0.12 | 0.14 | 0.14 | 0.15 | 0.16 | 0.17 | 0.16 | 0.17 | 0.19 | 0.21 | 0.25 |
| 16  | 0.06                     | 0.07 | 0.08 | 0.09 | 0.10 | 0.10 | 0.11 | 0.12 | 0.12 | 0.12 | 0.14 | 0.16 | 0.18 |
| 17  | 0.02                     | 0.02 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.06 |
| 18  | +0.02                    | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 |
| 19  | 0.06                     | 0.08 | 0.08 | 0.09 | 0.09 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.08 | 0.06 |
| 20  | 0.11                     | 0.14 | 0.15 | 0.17 | 0.17 | 0.18 | 0.18 | 0.18 | 0.19 | 0.19 | 0.18 | 0.15 | 0.11 |
| 21  | 0.16                     | 0.20 | 0.22 | 0.24 | 0.24 | 0.25 | 0.25 | 0.25 | 0.26 | 0.26 | 0.25 | 0.22 | 0.18 |
| 22  | 0.21                     | 0.26 | 0.29 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 0.33 | 0.34 | 0.32 | 0.29 | 0.25 |
| 23  | 0.27                     | 0.32 | 0.35 | 0.37 | 0.38 | 0.39 | 0.39 | 0.39 | 0.40 | 0.42 | 0.39 | 0.36 | 0.33 |
| 24  | 0.32                     | 0.38 | 0.41 | 0.43 | 0.44 | 0.46 | 0.46 | 0.47 | 0.47 | 0.50 | 0.46 | 0.43 | 0.40 |
| 25  | 0.37                     | 0.44 | 0.47 | 0.49 | 0.51 | 0.53 | 0.54 | 0.55 | 0.55 | 0.58 | 0.54 | 0.51 | 0.48 |
| 26  | 0.43                     | 0.50 | 0.54 | 0.56 | 0.58 | 0.60 | 0.61 | 0.62 | 0.62 | 0.66 | 0.62 | 0.58 | 0.55 |
| 27  | 0.49                     | 0.57 | 0.61 | 0.63 | 0.65 | 0.68 | 0.68 | 0.69 | 0.70 | 0.74 | 0.70 | 0.65 | 0.62 |
| 28  | 0.56                     | 0.64 | 0.68 | 0.70 | 0.72 | 0.76 | 0.76 | 0.78 | 0.78 | 0.82 | 0.78 | 0.72 | 0.70 |
| 29  | 0.63                     | 0.71 | 0.75 | 0.78 | 0.79 | 0.84 | 0.84 | 0.86 | 0.86 | 0.90 | 0.86 | 0.80 | 0.78 |
| 30  | 0.70                     | 0.78 | 0.82 | 0.87 | 0.87 | 0.92 | 0.92 | 0.94 | 0.94 | 0.98 | 0.94 | 0.88 | 0.86 |
| 35  | 1.10                     | 1.17 | 1.22 | 1.24 | 1.30 | 1.32 | 1.33 | 1.35 | 1.36 | 1.39 | 1.34 | 1.27 | 1.25 |
| 40  | 1.50                     | 1.61 | 1.67 | 1.71 | 1.73 | 1.79 | 1.79 | 1.80 | 1.82 | 1.83 | 1.78 | 1.69 | 1.65 |

## Volumetric Determination of Sugars.

Numerous methods and modifications have been proposed by which sugar may be determined volumetrically. However these methods are not so accurate as the gravimetric or polarimetric methods, which are generally preferred, although volumetric methods find considerable favour in biochemistry.

The following methods may be described :—

1. Fehling-Soxhlet method.
2. Allen's modification of Gerrard's method.
3. Benedict's methods (1907 and 1910).

### 1. *Fehling-Soxhlet Method.*

To obtain accurate results 10 cc. of the sugar must be equivalent to 10 cc. of Fehling's solution; if less than 10 cc. of sugar solution is required for titration, it must be diluted accordingly.

The Fehling's solution must be standardised so that 10 cc. = 0.05 gramm. glucose.

Standard invert sugar solution is prepared by dissolving 0.475 gramm. pure sucrose in about 50 cc. water, adding 1 cc. concentrated hydrochloric acid, and warming at 70° C. for 15 minutes, again cooling, neutralising and diluting to 100 cc.

10 cc. of Fehling's solution is brought into a porcelain basin or a small flask, 40 cc. of water added and raised to boiling point. The standard sugar solution is run into the gently boiling Fehling's solution, 1 cc. at a time, allowing complete reduction between each addition. The end-point is the disappearance of the blue colour, or the point at which the clear solution ceases to give a brown colour with Ling and Rendle's indicator.

The strength of the Fehling's solution must be adjusted until 10 cc. of the sugar solution are just reduced by 10 cc. of the Fehling's solution.

10 cc. Fehling's solution then = 0.05 gramm. glucose or invert  
= 0.0475 gramm. sucrose.

The actual sugar determination is carried out essentially as above. The first titration is in the nature of a trial; according to its indication the sugar solution must be diluted or concentrated so that about 10 cc. are required for 10 cc. Fehling's solution.

Ling and Rendle's indicator.

1 gramm.  $\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$  and 1 gramm.  $\text{NH}_4\text{CNS}$  are dissolved in 10 cc. of water at 120°F., cooled immediately, and 5 cc. of conc.  $\text{HCl}$  added. The solution may be decolorised by adding a small quantity of zinc dust, but its delicacy is decreased after it has been decolorised several times. For practical purposes the indicator may be too delicate, and it is

recommended to prepare it the day before it is required for use, as it gives the best results after the second decolorisation.

## 2. *Allen's modification of Gerrard's Method.*

Gerrard observed that the presence of KCN prevents the precipitation of  $\text{Cu}_2\text{O}$  from Fehling's solution when reduced by dextrose, etc.

Allen takes 10 cc. Fehling's solution and 40 cc. water, brings to boiling point, and runs in 5 per cent. potassium cyanide solution until the Fehling's solution is just decolorised, avoiding excess; another 10 cc. of Fehling's solution is now added, only this portion of Fehling's solution is reduced, therefore the preparation requires 0.05 gm. dextrose for its reduction as in the Fehling-Soxhlet method. The 0.5 per cent. (approximately) dextrose, or invert sugar solution, or inverted cane sugar solution is run carefully into the boiling Fehling's solution.

## 3. *Benedict's Method.*

The special reagent required is prepared as follows:—

200 gm.  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$  (or 100 gm.  $\text{Na}_2\text{CO}_3$ ),

200 gm. sodium citrate,

125 gm. KCNS,

are dissolved in water and made up to about 800 cc. Exactly 18 gm. of pure  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  are dissolved in 100 cc. water and added with constant stirring. 5 cc. of 5 per cent. potassium ferrocyanide solution are then added, and the whole diluted to 1000 cc. The effect of the ferrocyanide is to prevent precipitation of  $\text{Cu}_2\text{O}$ . The solution may be preserved.

25 cc. of Benedict's solution are pipetted into a porcelain basin 25–30 cm. diameter, 10–20 gm. crystallised sodium carbonate (or 5–10 gm. anhydrous sodium carbonate), and a piece of porous earthenware are added. The solution is boiled vigorously and the sugar solution run in until a heavy white precipitate is formed and the blue colour becomes distinctly paler. The sugar is now added carefully to the boiling solution till the blue colour has completely disappeared; towards the end an interval of 30 seconds between the drops of sugar solution should be given; water may be added to replace loss by evaporation.

The sugar solution should be 0.5–1 per cent. as in Fehling-Soxhlet method.

25 cc. reagent = 0.05 gm. dextrose = 0.053 gm. fructose.

## Interpretation of Results of Sugar Analysis.

### I. Cane Sugar.

All white crystalline sugars and candy contain over 99 per cent. sucrose, and an ash between 0.05 and 0.5 per cent.

The ash of cane sugars from beet contains less calcium and

$P_2O_5$ , but more potassium, than that from cane sugars from the sugar cane.

It is generally stated that 1 part of ash prevents the crystallisation of 5 parts of sugar. Briant states, however, that 1 part of ash prevents the crystallisation of 3.75 parts of sugar. One part of invert sugar prevents the crystallisation of 2 parts of sugar.

#### ANALYSES OF VARIOUS CANE SUGAR PRODUCTS.

| Variety of<br>Cane Sugar. | Sucrose<br>% | Invert<br>% | Ash<br>% | H <sub>2</sub> O<br>% | Proteins<br>% | Analyst              |
|---------------------------|--------------|-------------|----------|-----------------------|---------------|----------------------|
| Raw Jaggery               | 76.2         | 10.5        | 5.2      | 4.9                   | -             | L. Briant.           |
| Raw Penang                | 77.1         | 10.2        | 3.2      | 7.1                   | -             | "                    |
| Raw Egyptian              | 81.0         | 3.9         | 8.3      | 6.1                   | -             | "                    |
| Egyptian                  | 88.62        | 4.14        | 2.83     | 3.68                  | -             | H. Heron.            |
| "                         | 88.8         | 3.9         | 3.8      | 3.0                   | -             | F. Robinson          |
| Mauritius                 | 87.20        | 5.39        | 1.95     | 3.36                  | -             | H. Heron.            |
| Green Syrup               | 50.40        | 15.43       | 3.67     | 16.91                 | 2.38          | L. Briant.           |
| Treacle                   | 34.39        | 26.30       | 4.91     | 17.06                 | 2.53          | "                    |
| Molasses                  | 48.0         | 18.0        | 1.4      | 31.1                  | -             | "                    |
| Refined "Moist"           | 85.24        | 6.54        | 1.74     | 3.57                  | 0.65          | "                    |
| American Cane Syrup       | 34.98        | 31.79       | 6.50     | 23.55                 | 0.81          | "                    |
| Sugar Cane                | 11-16        | 0.4-1.5     | 0.5-1.0  | -                     | -             | Prinsen<br>Geerligs. |
| Beet Juice                | 15           | -           | 0.8      | -                     | 1.6           | "                    |
| Partially Refined Cane    | 93.4         | -           | 0.9      | 1.3                   | -             | F. Robinson.         |
| "                         | 87.5         | 6.2         | 0.8      | 3.5                   | -             | "                    |

For brewing purposes partially refined canes are generally used and give a brewer's extract (*i.e.*, brewer's lbs. per 2 cwt. of sugar) of about 84-86. The brewers' extract of a sugar is obtained by multiplying the excess Sp. Gr. over 1000 of a 10 per cent. solution by 2.24.

#### II. Invert Sugar.

Three qualities are generally produced, being commercial as No. 1, No. 2, and No. 3 invert sugars.

The sucrose (uninverted cane sugar) should be between 0.8 and 2 per cent.

The following are Briant's standards for invert sugars for brewing purposes:—

|               | No. 1.<br>Per cent. | No. 2.<br>Per cent. |
|---------------|---------------------|---------------------|
| Invert Sugar  | > 76                | > 74                |
| Sucrose       | < 1.5               | < 2.0               |
| Ash           | < 1.5               | < 2.0               |
| Unfermentable | < 2.5               | < 3.0               |
| Fe.O.         | < 0.005             | < 0.02%             |
| S.B.P.        | > 10                | > -7                |



H. Heron gives the following as average figures for the different qualities. The dextrose and lævulose are expressed separately, and it will be noticed the lævulose is always the lower; this is due to the destructive action of the inverting acid; the difference should not, however, be greater than 5-6 per cent. on a carefully inverted sample:

|  | No. 1. | No. 2. | No. 3. |
|--|--------|--------|--------|
| Dextrose                               | 38.0   | 37.0   | 36.0   |
| Lævulose                               | 36.6   | 34.8   | 31.1   |
| Sucrose                                | 2.0    | 2.0    | 2.5    |
| Ash                                    | 1.5    | 2.0    | 3.5    |
| Proteins                               | 0.2    | 0.4    | 0.6    |
| Moisture                               | 17.7   | 18.8   | 19.8   |
| Unfermentable matter                   | 4.0    | 4.5    | 6.5    |
| Extract in brewers' lbs.<br>for 2 cwt. | 72.5   | 72.5   | 72.0   |

It should be mentioned that glucose is sometimes added to invert sugar to cheapen the cost of production, for improving the colour, and to assist solidification. The  $[\alpha]_D$  gives rapid information in this direction; the addition of glucose decreases the negative rotation.

### III. Starch Sugar (Glucose).

This is commercial in the form of chips and syrups. It varies considerably in composition, but for brewing purposes Briant gives the following:

|                      | Per cent |
|----------------------|----------|
| Dextrose and Maltose | >65      |
| Dextrin              | 1-2      |
| Protein              | 0.5-1.5  |
| Ash                  | 1-1.7    |

The following figures are for glucose chips (F. Robinson):

|                               | Per cent. | Per cent. | Per cent. | Per cent. |
|-------------------------------|-----------|-----------|-----------|-----------|
| Dextrose                      | 68.4      | 55.9      | 64.1      | 63.0      |
| Maltose                       | 9.6       | 10.3      | 13.11     | 15.3      |
| Ash                           | 0.9       | 1.6       | 1.09      | 0.84      |
| Moisture                      | 11.1      | 14.0      | 16.17     | 13.1      |
| Proteins                      | 0.36      | 0.77      | 5.53      | 7.8       |
| Unfermentable                 |           |           |           |           |
| Dextrin, Gallisin, etc.       | 8.94      | 17.43     |           |           |
| Brewers' extract per 224 lbs. | 77.0      | 75.8      | 73.5      | 73.0      |

Glucose and dextrin-maltose syrups are very variable in composition. The ash should be <1.0, and proteins <1.0 per cent., and of sulphites (used for bleaching) there should be as little as possible. Confectioners' glucose syrup is quite colourless.



## ANALYSIS OF DEXTRIN MALTOSE SYRUPS. (H. Heron.)

|                               | Per cent. | Per cent. |
|-------------------------------|-----------|-----------|
| Maltose                       | 35.13     | 17.63     |
| Dextrose                      | 19.35     | 14.32     |
| Dextrin and Unfermentable     | 24.83     | 48.60     |
| Ash                           | 0.76      | 1.01      |
| Proteins                      | 0.85      | 0.79      |
| Water                         | 19.08     | 17.65     |
| Brewers' extract per 224 lbs. | -         | 71.7      |

## 4. Determination of Pentoses and Pentosans.

Pentoses, if present alone in solution, can be determined by Fehling's solution, but generally a mixture of carbohydrates is present, and in this case the pentose is estimated by converting into furfural by distillation with hydrochloric acid, combining the furfural with phloroglucinol and weighing the phloroglucide.

Material to give 0.03-0.3 grm. phloroglucide is taken. The apparatus consists of a flask provided with a tap funnel and a connecting tube with a trap leading to a condenser. The weighed quantity is distilled with 100 cc. of 12 per cent. hydrochloric acid at such a rate that 30 cc. pass over in 10 minutes, the distillate being filtered through a small filter paper as collected. When 30 cc. have distilled over 30 cc. of dilute acid are added to the flask from the tap funnel, and the distillation continued another 10 minutes. This addition is continued 12 times, or until about 360 cc. of distillate have been collected. Completion of distillation is tested for by means of aniline acetate on filter paper; when no red colour appears distillation is complete. To the whole of the distillate about double the amount of pure phloroglucinol required, dissolved in 12 per cent. HCl, is added, and the mixture well stirred. The liquid becomes yellow, then green, and finally a precipitate settles out which is first green but subsequently becomes black. The volume is made up to 400 cc., and after standing for 12 hours the precipitate is collected on a weighed filter paper, washed with 150 cc. water, dried at 100° C. for 4 hours, and weighed.

$$\text{Furfural} = (a + 0.0052) \times 0.5185.$$

$$\text{Pentose} = (a + 0.0052) \times 1.0075.$$

$$\text{Pentosan} = (a + 0.0052) \times 0.8866.$$

$a$  = the weight of phloroglucide.

0.0052 = the weight of phloroglucide which remains in solution under the above conditions.

The phloroglucinol used must be free from diresorcinol. This latter gives a violet colour on heating nearly to the boil with a few drops of acetic anhydride. cooling, and adding a few drops of concentrated  $\text{H}_2\text{SO}_4$ .

## 5. Starch.

## Determination of Starch.

1. *Ewer's Method* (1908).

25 cc. of glacial acetic acid is run into a 200 cc. flask without wetting the neck. 5 gram. of the finely-ground material is added, the flask closed, and well shaken until the mixture is uniform. The stopper and neck of the flask are then washed down with a further 20 cc. of glacial acetic acid. The flask is now placed in a boiling water bath for 10 minutes, then 10 cc. of hydrochloric acid (1 in 10) is added, and the flask.

## Water Content of Starch (Scheibler).

On treatment with alcohol of 90°Tr. (90 per cent. by volume), starch containing more than 11.4 per cent. of water gives up the excess water to the alcohol; starch containing less than 11.4 per cent. of water takes up water from the alcohol.

100 cc. of the above alcohol (83.39 gram.) are shaken with  $\frac{83.39}{2} = 41.7$  gram. of starch, and the Sp. Gr. of the filtrate determined.

| Sp. Gr.<br>filtrate. | % Water<br>in starch. | Sp. Gr.<br>filtrate. | % Water<br>in starch. | Sp. Gr.<br>filtrate. | % Water<br>in starch. |
|----------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|
| 0.8226               | 0                     | 0.8455               | 22                    | 0.8643               | 44                    |
| 234                  | 1                     | 465                  | 23                    | 651                  | 45                    |
| 243                  | 2                     | 474                  | 24                    | 658                  | 46                    |
| 253                  | 3                     | 484                  | 25                    | 665                  | 47                    |
| 262                  | 4                     | 493                  | 26                    | 673                  | 48                    |
| 271                  | 5                     | 502                  | 27                    | 680                  | 49                    |
| 281                  | 6                     | 511                  | 28                    | 688                  | 50                    |
| 291                  | 7                     | 520                  | 29                    | 696                  | 51                    |
| 300                  | 8                     | 529                  | 30                    | 703                  | 52                    |
| 311                  | 9                     | 538                  | 31                    | 710                  | 53                    |
| 323                  | 10                    | 547                  | 32                    | 716                  | 54                    |
| 335                  | 11                    | 555                  | 33                    | 723                  | 55                    |
| 346                  | 12                    | 563                  | 34                    | 731                  | 56                    |
| 358                  | 13                    | 571                  | 35                    | 738                  | 57                    |
| 370                  | 14                    | 579                  | 36                    | 745                  | 58                    |
| 382                  | 15                    | 587                  | 37                    | 753                  | 59                    |
| 394                  | 16                    | 595                  | 38                    | 760                  | 60                    |
| 405                  | 17                    | 603                  | 39                    | 767                  | 61                    |
| 416                  | 18                    | 612                  | 40                    | 775                  | 62                    |
| 426                  | 19                    | 620                  | 41                    | 783                  | 63                    |
| 436                  | 20                    | 627                  | 42                    | 791                  | 64                    |
| 446                  | 21                    | 635                  | 43                    | 798                  | 65                    |

left in the water-bath for exactly 6 minutes, shaking thoroughly every minute. Hot water is now added, the volume made up to 180 cc., and the mixture is heated for a further 15 minutes in the boiling water bath. The solution is cooled, clarified by adding 25 cc. of potassium ferrocyanide, made up to the mark with water, filtered, and polarised. If the filtrate is difficult to obtain clear, a few crystals of zinc sulphate are added to assist clarification.

Ewer found corrections were necessary owing to the presence of optically active bodies other than starch. A "blank" is therefore carried out as follows:—

5 grm. of the finely-ground material are added to 70 cc. of water at about 120°F. in a 100 cc. flask, and the whole thoroughly mixed by vigorous shaking. After digestion at the ordinary temperature for 1 hour, 25 cc. of glacial acetic acid are added and digestion continued for half an hour; after this the temperature is adjusted to 60°F., potassium

### Water Content of Starch (Saare).

100 grm. potato starch are rinsed into tared 250 cc. flask, water at 17.5°C. added to the mark, and the flask and contents weighed.

| Grm. starch<br>+ water. | % water<br>in starch | Grm. starch<br>+ water. | % water<br>in starch. | Grm. starch<br>+ water. | % water<br>in starch. |
|-------------------------|----------------------|-------------------------|-----------------------|-------------------------|-----------------------|
| 289.40                  | 0                    | 281.10                  | 21                    | 272.85                  | 42                    |
| 289.00                  | 1                    | 280.75                  | 22                    | 272.45                  | 43                    |
| 288.60                  | 2                    | 280.35                  | 23                    | 272.05                  | 44                    |
| 288.20                  | 3                    | 279.95                  | 24                    | 271.70                  | 45                    |
| 287.80                  | 4                    | 279.55                  | 25                    | 271.30                  | 46                    |
| 287.40                  | 5                    | 279.15                  | 26                    | 270.90                  | 47                    |
| 287.05                  | 6                    | 278.75                  | 27                    | 270.50                  | 48                    |
| 286.65                  | 7                    | 278.35                  | 28                    | 270.10                  | 49                    |
| 286.25                  | 8                    | 278.00                  | 29                    | 269.70                  | 50                    |
| 285.85                  | 9                    | 277.60                  | 30                    | 269.30                  | 51                    |
| 285.45                  | 10                   | 277.20                  | 31                    | 268.90                  | 52                    |
| 285.05                  | 11                   | 276.80                  | 32                    | 268.50                  | 53                    |
| 284.65                  | 12                   | 276.40                  | 33                    | 268.10                  | 54                    |
| 284.25                  | 13                   | 276.00                  | 34                    | 267.75                  | 55                    |
| 283.90                  | 14                   | 275.60                  | 35                    | 267.35                  | 56                    |
| 283.50                  | 15                   | 275.20                  | 36                    | 266.95                  | 57                    |
| 283.10                  | 16                   | 274.80                  | 37                    | 266.55                  | 58                    |
| 282.70                  | 17                   | 274.40                  | 38                    | 266.15                  | 59                    |
| 282.30                  | 18                   | 274.05                  | 39                    | 265.75                  | 60                    |
| 281.90                  | 19                   | 273.65                  | 40                    |                         |                       |
| 281.50                  | 20                   | 273.25                  | 41                    |                         |                       |

ferrocyanide added, the mixture diluted to 100 cc., filtered and polarised as before.

For rice starch at 68°F.  $[\alpha]_D = 186.07$

For maize starch at 68°F.  $[\alpha]_D = 184.19$

on 5 per cent. solutions (the concentration has only a slight influence within reasonable limits).

Thus, if after correction for the blank the  $[\alpha]_D$  obtained = 130,

$$\text{Starch in the maize} = \frac{130 \times 100}{184.19} = 70.7 \text{ per cent}$$

## 2. C. O'Sullivan's Method (1884).

The starch is gelatinised and converted into maltose and dextrin by diastase (cold water extract of malt). Oil and soluble carbohydrates must first be removed.

*Method.* 5 grm. of the grain are extracted with ether in a Soxhlet to remove fat, after which the residue is transferred to a beaker with 1 litre of cold water, allowed to stand about 24 hours and the clear supernatant liquid decanted through a filter, the residue being washed with water at 35°C. The grain is now transferred to a small beaker, using 40 cc. water, and gradually heated up to boiling in a water-bath, with constant stirring to avoid formation of lumps. After boiling in the bath for about 10 minutes it is cooled to 62.8°C. (145°F.) and 10 cc. of extract of malt added (see below).

A correction for the extract of malt is necessary, therefore 10 cc. of the extract of malt with about 40 cc. water are digested along with the starch experiment, and the same determinations made as with the starch experiment.

The digestions at 62.8°C. (145°F.) are allowed to proceed for about 1 hour until all starch has become hydrolysed and no trace of starch can be detected with iodine; the mixtures are then raised to boiling for 10 minutes, cooled, made up to 200 cc., and filtered through dry paper into dry beakers.

In the filtrates are determined—

1. The copper reduction by the Brown, Morris and Millar method as given under "Sugar analysis," taking 10 cc. of the converted starch solution.

2. The rotation in degrees.

*Maltose.* From the weights of CuO obtained, the maltose is obtained by the table given under analysis of glucose.

Maltose from 5 grm. grain = M.

Maltose from 10 cc. malt extract = m.

$$\text{Maltose percentage from grain} = (M - m) \frac{100}{5}$$

$$\text{giving an } [\alpha]_D \text{ of } (M - m) \frac{100}{5} \times \frac{138}{100}$$

*Dextrin.*

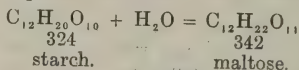
R = reading in 2 dm. tube after subtracting reading due to malt extract.

$$[\alpha]_D = \frac{R \times 100}{2 \times 2.5}$$

$$[\alpha]_D \text{ due to dextrin} = \frac{R \times 100}{2 \times 2.5} - (M - m) \frac{138}{5}$$

$$\% \text{ Dextrin} = \left[ \frac{R \times 100}{2 \times 2.5} - (M - m) \frac{138}{5} \right] \frac{100}{202}$$

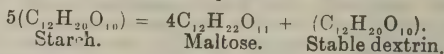
Starch gives an equal quantity of dextrin, and 95 parts starch give 100 parts maltose.



Maltose  $\times 0.95 = \text{starch}\%$  } The total gives the starch  
Dextrin  $= \text{starch}\%$  } % in the grain investigated.

3. *H. Brown's Method* (*Trans. Guinness Research Lab.*, 1903, Vol. I, pt. 1, p. 88).

H. Brown and Heron found that unrestricted diastase always hydrolyses starch to the same stage, namely, that expressed by their "No. 8" equation :



i.e., 100 parts of starch give 84.4 parts of maltose, therefore by determining the maltose after action of unrestricted diastase the amount of starch can be calculated.

2.5 grm. material are placed in the thimble of the extraction apparatus and extracted with alcohol. Alcohol of Sp. Gr. 0.920 is placed in the flask, as the alcohol which then syphons over has the required Sp. Gr. of 0.900, and the temperature inside the extractor remains at 35°–40°C.

The contents of the thimble are then transferred to a beaker and boiled with about 100 cc. of water. After cooling to 57°C. (134°F.), 10 cc. of active malt extract are added and conversion allowed to proceed for 1 hour. The liquid is boiled, filtered into a 200 cc. flask, the residue well washed, and the filtrate and washings made up to 200 cc. The copper-reducing power is determined on 20 cc. by Brown, Morris and Millar's method, and the maltose obtained by their table.

84.4 parts maltose = 100 parts starch, and hence the percentage may be found.

The precautions to be taken are:—

1. Time required for extraction of ready-formed sugars is at least 3 hours for barley and 9 hours for malt.
2. The malt extract should be prepared from a malt dried at 50°–52°C. having a D.A. of 80 Lintner. (See Diastatic activity under “Malt.”)

If a malt of higher D.A. is used, about 7–10 per cent. more maltose is obtained, if one of only 40 D.A., then only 81·7 per cent. of maltose is obtained.

#### 4. *Davis and Daish's Method* (1914).

In this method taka-diastase is used to convert the starch completely into glucose and maltose.

The material is extracted with alcohol in a Soxhlet for 18–24 hours; the soluble carbohydrates are generally removed when the extract becomes colourless.

In the case of living plant tissues, etc., the material previous to extraction is plunged into boiling 95 per cent. alcohol containing 1 per cent. by volume of ammonia (0·880); the enzymes are thereby killed. After the Soxhlet extraction such tissues require drying for 18 hours in a steam oven, grinding, and 10 grm. drying to a constant weight in a vacuum at 100°–110°C. over  $P_2O_5$ , so as to obtain the weight of dry substance previous to starch estimation.

The dry material from above (or the material from the extraction apparatus if drying not required)—if necessary previously extracted with water for 24 hours, filtered and washed to remove gums, etc.—is gelatinised by heating to the boil (in water-bath) with 200 cc. of water, cooled to 38°C., and 0·1 grm. taka-diastase and 2 cc. of toluene (as an antiseptic) are added, and the mixture left for 24 hours at 38°C. It is then washed by decantation, through a filter, until the filtrate amounts to 475 cc., precipitated with lead acetate, avoiding a large excess (with plant tissues 5·25 cc. required), diluted to 500 cc., and filtered. 100 cc. of the filtrate are precipitated with sodium carbonate and made up to 110 cc., filtered, and the rotation and copper reduction (on 50 cc. by Brown, Morris and Millar method) determined.

From the CuO the total Cu from 100 grm. material is calculated, and the gram values for dextrose and maltose ascertained from Brown, Morris and Millar's tables.

The rotation is calculated to the  $[\alpha]_D$  on the material, and from these values the glucose and maltose are calculated by the equations given under starch sugars (glucose).

$$\begin{array}{l} \text{Glucose} \times 0\cdot90 = \text{starch.} \} \\ \text{Maltose} \times 0\cdot95 = \text{starch.} \} \end{array}$$



# BREWING MATERIALS.

F. ROBINSON, M.Sc. Tech., B.Sc., F.I.C.

## I. Water.

The following determinations are made (in part or completely) :—

Suspended matter.

Free and saline ammonia

Albuminoid ammonia.

Oxygen absorption.

Nitrites.

Nitrates.

} See " Water Analysis " Section.

Examination by Hansen's method.

Examination for *B. coli*.

In addition to the remarks noted under Interpretation of Results (" Water Analysis " section), Sykes and Ling state that as a general rule, neither the free nor the albuminoid  $\text{NH}_3$  in a brewing water should exceed 0.1 part per million, and consider that the oxygen absorbed may probably be allowed to rise as high as 0.25 part per 100,000 for brewing purposes. They further consider that in brewing waters the nitrates may rise to 1.5 grains per gallon, and excellent beers have been produced with waters containing 2.5 grains of nitrate per gallon; with such large amounts of nitrates present, the water must be organically pure in other respects.

Nitrates in excess cause rapid weakening of the yeast, apparently due to their reduction to nitrites; they also seem to favour the growth of bacteria at the expense of the yeast. Briant gives as the limits 2.5 grains nitrates per gallon in soft water, and 4 grains in hard water. Waters containing nitrates naturally, i.e. not as the result of pollution, are usually hard waters.

Hansen's method of examining brewing waters is sometimes employed, for which the works of Jörgensen, Klöcker, etc., may be consulted.

### Factors for Calculating Amount of Water Treatment.

1 fluid oz. satd.  $\text{CaCl}_2$  soln. (Sp. Gr. 1380) per barrel gives 10 grains  $\text{CaCl}_2$  per gallon.

1 fluid oz. 45%  $\text{MgCl}_2$  soln. (Sp. Gr. 1160) per barrel gives 7.5 grains  $\text{MgCl}_2$  per gallon.

1 ounce  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  per barrel gives 6.0 grains  $\text{MgSO}_4$  per gallon.

1 ounce  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  (ground gypsum) per barrel gives 9.53 grains  $\text{CaSO}_4$  per gallon.

A solution of kainit is frequently used to supply both  $\text{NaCl}$  and  $\text{MgSO}_4$ ; the quantity of any such solution required is only decided when its analysis is known.



# Water Suitable for Different Types of Beers

As Burton waters have long been noted for the brewing of pale ale, while Dublin and London waters are more suitable for stouts, analyses of these waters are given below in grains per gallon for salts, and parts per million for  $\text{NH}_3$  and  $\text{O}_2$  :

|  | Burton<br>well<br>water.<br>Briant. | Burton<br>deep well<br>water.<br>Briant. | Burton<br>deep well<br>water.<br>E. Brown. | London<br>Deep well water.<br>Briant. | London<br>Moritz and<br>Morris. | Dublin<br>well.<br>Sykes and<br>Ling.   | Water for<br>mild ales.<br>Sykes and<br>Ling. |
|--|-------------------------------------|--|--|---------------------------------------|---------------------------------|---|---|
| $\text{NaCl}$                          | 9.35                                | 2.54                                     | 3.90                                       | 10.51                                 | 8.54                            | 1.83  | 35.14   |
| $\text{CaCl}_2$                        | -                                   | -  | -  | -                                     | -                               | -   | 3.88  |
| $\text{CaSO}_4$                        | 59.43                               | 63.65                                    | 77.87                                      | -                                     | -                               | 4.45  | 6.23  |
| $\text{CaCO}_3$                        | -                                   | -  | 7.62                                       | 5.60                                  | 5.37                            | 14.21   | 16.37   |
| $\text{K}_2\text{SO}_4$                | 0.76                                | 0.15                                     | 1.59                                       | -                                     | -                               | -   | -   |
| $\text{NaNO}_3$                        | -                                   | -  | 1.97                                       | -                                     | -                               | -   | -   |
| $\text{Na}_2\text{SO}_4$               | -                                   | 1.03                                     | 10.21                                      | 14.14                                 | 16.65                           | -   | -   |
| $\text{MgCO}_3$                        | 15.83                               | 13.40                                    | 21.31                                      | 1.47                                  | 3.82                            | 0.90  | 4.01  |
| $\text{SiO}_2 + \text{Al}_2\text{O}_3$ | -                                   | -  | 0.98                                       | -                                     | 0.39                            | $\begin{cases} \text{SiO}_2 & = 0.26 \\ \text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3 & = 0.24 \end{cases}$ | 0.22  |
| $\text{MgSO}_4$                        | 6.39                                | 8.97                                     | -  | -                                     | -                               | -   | -   |
| $\text{Ca}(\text{NO}_3)_2$             | 0.41                                | 1.33                                     | -  | -                                     | 0.69                            | -   | -   |
| $\text{Na}_2\text{CO}_3$               | -                                   | -  | -  | 10.01                                 | 8.25                            | -   | -   |
| $\text{NH}_3$ free                     | 0.015                               | nil                                      | -  | 0.32                                  | -                               | -   | -   |
| $\text{NH}_3$ albuminoid               | 0.065                               | 0.050                                    | -  | 0.05                                  | -                               | -   | -   |
| $\text{O}_2$ absorbed                  | 0.790                               | 0.550                                    | -  | 0.60                                  | -                               | -   | -   |

## Quantities of Various Salts in Waters for Various Beers.

| Quality of Beer. |                   | Sykes and Ling. | Grains per gallon. |                    |      |
|------------------|-------------------|-----------------|--------------------|--------------------|------|
|                  |                   |                 | Briant.            | Moritz and Morris. |      |
| Mild.            | NaCl              | 35              | 40—75              | 10—20              | —    |
|                  | CaSO <sub>4</sub> | 10—20           | —                  | —                  | —    |
|                  | MgCl <sub>2</sub> | 15              | —                  | —                  | —    |
|                  | MgSO <sub>4</sub> | —               | —                  | —                  | —    |
|                  | CaCl <sub>2</sub> | 5               | —                  | —                  | <5   |
| Pale and Bitter. | NaCl              | —               | —                  | —                  | —    |
|                  | CaCl <sub>2</sub> | 10              | —                  | —                  | <6   |
|                  | MgSO <sub>4</sub> | —               | —                  | —                  | —    |
|                  | CaSO <sub>4</sub> | 40—50           | —                  | —                  | 6—10 |

For stouts (*i.e.* black beers) Na<sub>2</sub>SO<sub>4</sub> and Na<sub>2</sub>CO<sub>3</sub> may be useful, but their addition does not improve a water sufficiently free from CaSO<sub>4</sub> and MgSO<sub>4</sub>; in such a case Na<sub>2</sub>CO<sub>3</sub> is added to precipitate CaSO<sub>4</sub> and MgSO<sub>4</sub>.

1 grain CaSO<sub>4</sub> requires 2.1 grains Na<sub>2</sub>CO<sub>3</sub>.10H<sub>2</sub>O, or 1.28 grains K<sub>2</sub>CO<sub>3</sub>.2H<sub>2</sub>O.

1 grain MgSO<sub>4</sub> requires 2.38 grains Na<sub>2</sub>CO<sub>3</sub>.10H<sub>2</sub>O, or 1.45 grains K<sub>2</sub>CO<sub>3</sub>.2H<sub>2</sub>O.

Over 50 grains NaCl per gallon causes weakening of the yeast. (Milk contains about 120 grains per gallon.)

Over 75 grains CaSO<sub>4</sub> per gallon causes slow conditioning and clearing.

Ounces per barrel  $\times 12.15$  = grains per gallon.

## Substances Used in Water Treatment.

*Calcium Chloride solution.*

The commercial article is a saturated solution, containing an average of 3,600 grains CaCl<sub>2</sub> per gallon, with a variation of 3 or 4 per cent.

The Sp. Gr. varies from about 1.360 to 1.395.

*Gypsum.*

The best form in which to use this is precipitated calcium sulphate in the form of a very stiff paste; this is more easily soluble than ground gypsum, but even in this paste a few hard gritty particles remain (varying in quantity with the sample) more difficult than the main bulk to dissolve. The product varies considerably in moisture; hence the CaSO<sub>4</sub> may vary as much as 15 per cent., and it is very desirable that every batch be tested. It is quite possible to maintain the per cent. CaSO<sub>4</sub> constant within  $\pm 2$  on different batches. Commercial gypsum pastes contain between 43 per cent. and 53 per cent. CaSO<sub>4</sub>.

A rapid method of determining the moisture is by careful ignition.

**Kainit solution.**

Pure kainit ( $K_2SO_4$ ,  $MgSO_4$ ,  $MgCl_2 \cdot 6H_2O$ ) is not met with commercially, and the product obtained is largely contaminated with NaCl. For use in brewing it is sold as a strong solution of Sp. Gr. about 1.212.

The analysis is carried out by ordinary analytical methods, and the following is a specimen analysis of such a commercial solution.

**Kainit solution (F. Robinson).**

|           |                          |          |                          |
|-----------|--------------------------|----------|--------------------------|
| NaCl      | 8,580 grains per gallon. | $MgSO_4$ | 3,255 grains per gallon. |
| $MgCl_2$  | 3,148     "     "        | $SiO_2$  | 37     "     "           |
| $K_2SO_4$ | 5,503     "     "        |          |                          |

**2. Malt.****Commercial Methods of Malt Analysis.**

The following is an abstract of the Standard Method of Analysis as recommended by the Malt Analysis Committee of the Institute of Brewing (*Journ. Inst. Brew.*, 1906, **12**, 1; 1910, **16**, 529; and 1922, **28**, 775).

**Sampling.****PALE MALTS.**

In the case of deliveries, samples should be drawn from at least 10 sacks if the consignment amounts to over 100 sacks, or if the parcel be smaller, then from 10 per cent. of the number of sacks. The sample should be drawn, not from the surface of a sack, but with a spear from a depth at least 6 ins. from the surface.

These bulk samples should be put into a large tin kept for the purpose, and well shaken; a smaller tin (at least a pint capacity) is then filled from the larger one, and sent to the analyst, the remainder being reserved in other small tins if the analysis is to be checked. The lids of all tins containing samples for analysis should fit well, and it is desirable to affix gummed paper round the junction of the lid and tin. Well dried and stoppered bottles are more suitable.

In sampling malts from heaps, surface samples should be avoided as in the case of sacks, and six to twelve samples should be withdrawn and mixed in a large tin; a small tin or bottle being filled with a portion of the mixture and sent for analysis. When the malt lies in bins, a sample from the spout will generally fairly represent the bulk if the bin has been drawn upon. If not, the bin should be probed at different depths, five or six samples withdrawn, mixed in a large tin, and a small tin or bottle filled from the mixture and sent for analysis.

Either the "Seck" or the "Boby" mill should be used for all estimations, except that of moisture, where a coffee mill may be employed. The rolls must be checked at 0.5 mm. at

frequent intervals by means of a feeler-gauge. In order to allow for loss in the mill, a quantity of malt, slightly in excess of that required for each determination, is to be separately weighed out and ground. Finally, the exact amounts of grist, subsequently required for the various determinations, are weighed out. It is not permissible to grind at the outset sufficient malt for all the determinations, and to weigh out the various quantities from this grist.

To check the results, the analyst should lay in a stock of a certain malt at the commencement of the season, and each working day the extract, diastatic activity and moisture of this stock malt should be estimated, no results for other samples being accepted when the results with the stock malt show any appreciable divergence from the normal values. The stock malt should be taken from one kilning, and must be kept in an air-tight vessel.

### Extract.

54 grm. of malt are ground in the Seck mill, and of the grist exactly 50 grm. are weighed out and washed in a copper, porcelain, or glass beaker with 360 cc. of distilled water previously heated to 155°F. The beaker is covered with a clock-glass and maintained at 150°F. in a water-bath for one hour, stirring at 10 minute intervals. The whole mash is then washed into a 515 cc. flask, cooled to 60°F. and diluted up to 515 mark (the 15 cc. is to allow for the volume occupied by the grains). The flask is well shaken, and the mash filtered, the first 50 cc. being returned. When about 250 cc. have been collected, the Sp. Gr. of the filtrate is determined with the Sp. Gr. bottle at 60°/60°F. The excess Sp. Gr. over water (= 1000) multiplied by 3.36 gives the extract in brewers' lbs. per standard quarter of malt.

If preferred, the mashing can be carried out directly in the 515 cc. measuring flask. In this case the mash should be shaken at intervals of about 10 minutes.

It is more convenient in summer to determine the Sp. Gr. of the wort at  $t^{\circ}/t^{\circ}$ . The correct Sp. Gr. (S. 60°/60°) is related to the apparent Sp. Gr. at  $t^{\circ}$ F. (S.  $t^{\circ}/t^{\circ}$ ) as follows:

$$\text{S. } 60^{\circ}/60^{\circ} = \text{S. } t^{\circ}/t^{\circ} + (t - 60) 0.02.$$

### Tint.

This is determined in the Lovibond tintometer. The filtrate (wort) from the extract determination, which must be perfectly bright, is placed at once in a 1 in. cell (with glass ends), and its tint recorded in colour units of the series "52" glasses, by comparison in the Lovibond instrument. Direct sunlight should not be used, and the light must fall equally on both halves of the porcelain screen, so that both the cell and comparison glasses are equally illuminated. After noting the

tint, the cell and the comparison glasses should be reversed and another reading taken; with uniform illumination of the screen this reading will be equal to that previously taken.

### Moisture.

About 5 grm. of malt are accurately weighed out in a weighing bottle 2 in. in diameter and 1 in. deep, and heated for three hours in a boiling water oven. The loss in weight is taken as the moisture, and the result should be returned as the nearest 0.1%.

### SPECIFIC GRAVITY AND CORRESPONDING "EXTRACT." (Brewers' lbs. per Quarter.)

| Sp. Gr.<br>of Wort. | Extract. | Sp. Gr.<br>of Wort. | Extract. | Sp. Gr.<br>of Wort. | Extract |
|---------------------|----------|---------------------|----------|---------------------|---------|
| 1022.5              | 75.6     | 1025.1              | 84.3     | 1027.6              | 92.7    |
| .6                  | 75.9     | .2                  | 84.7     | .7                  | 93.0    |
| .7                  | 76.3     | .3                  | 85.0     | .8                  | 93.4    |
| .8                  | 76.6     | .4                  | 85.3     | .9                  | 93.7    |
| .9                  | 76.9     | .5                  | 85.7     | 1028.0              | 94.1    |
| 1023.0              | 77.3     | .6                  | 86.0     | .1                  | 94.4    |
| .1                  | 77.6     | .7                  | 86.3     | .2                  | 94.7    |
| .2                  | 77.9     | .8                  | 86.7     | .3                  | 95.1    |
| .3                  | 78.3     | .9                  | 87.0     | .4                  | 95.4    |
| .4                  | 78.6     | 1026.0              | 87.4     | .5                  | 95.7    |
| .5                  | 78.9     | .1                  | 87.7     | .6                  | 96.1    |
| .6                  | 79.3     | .2                  | 88.0     | .7                  | 96.4    |
| .7                  | 79.6     | .3                  | 88.4     | .8                  | 96.7    |
| .8                  | 79.9     | .4                  | 88.7     | .9                  | 97.1    |
| 9                   | 80.3     | .5                  | 89.0     | 1029.0              | 97.4    |
| 1024.0              | 80.6     | .6                  | 89.4     | .1                  | 97.8    |
| .1                  | 81.0     | .7                  | 89.7     | .2                  | 98.1    |
| .2                  | 81.3     | .8                  | 90.0     | .3                  | 98.4    |
| .3                  | 81.6     | .9                  | 90.4     | .4                  | 98.8    |
| .4                  | 81.9     | 1027.0              | 90.7     | .5                  | 99.1    |
| .5                  | 82.3     | .1                  | 91.0     | .6                  | 99.5    |
| .6                  | 82.6     | .2                  | 91.4     | .7                  | 99.8    |
| .7                  | 82.9     | .3                  | 91.7     | .8                  | 100.1   |
| .8                  | 83.3     | .4                  | 92.0     | .9                  | 100.5   |
| .9                  | 83.6     | .5                  | 92.4     | 1030.0              | 100.8   |
| 1025.0              | 84.0     |                     |          |                     |         |

### Diastatic Activity (Lintner Value).

25 grm. of ground malt are extracted with 500 cc. of distilled water for three hours at 70°F., well stirred every half hour, filtered bright, and the first 100 cc. rejected. A portion of the filtrate (3 or 4 cc.) is allowed to act on 100 cc. of a 2 per cent. solution of soluble starch (see below) at 70°F. for one hour in a 200 cc. flask. 10 cc. of N/10 caustic soda is added to stop further diastatic action, the liquid cooled to 60°F. and diluted to 200 cc. with distilled water, shaken well, and titrated against 5 cc. portions of Fehling's solution, using Ling and Rendle's indicator (see Volumetric determination of sugars, "Carbohydrates" Section).

5 cc. of Fehling's solution are measured into a boiling flask,

and raised to the boil over a small Bunsen flame. The converted starch solution is added from a burette, in 5 cc. quantities at first, the mixture being kept rotated and boiled after each addition until reduction of the copper is complete, which is ascertained by rapidly withdrawing a drop of liquid on a glass rod, and bringing it at once in contact with a drop of the indicator on a porcelain spot plate.

$$\text{D.A.} = \frac{1000}{XY}$$

D.A. = Diastatic activity.

X = the number of cc. of malt extract contained in 100 cc. of the fully diluted starch conversion liquid.

Y = the number of cc. of same liquid required for the reduction of 5 cc. of Fehling's solution.

The above method (using 3 cc. malt extract to 100 cc. of 2 per cent. soluble starch solution) is not accurate for malts having a diastatic capacity exceeding 50° Lintner; in the case of such malts the relative volume of malt extract must be less, say 2 cc., or, for malts of the highest diastatic capacity, such as are frequently used by distillers and vinegar makers (*i.e.* malts over 80° Lintner), an even smaller volume of extract must be taken.

#### DIASTATIC ACTIVITY (DEGREES LINTNER).

100 cc. 2 per cent. soluble starch + 4 cc. malt extract per 200 cc.

The table gives the cc. of the diluted starch conversion used in the titration.

| cc.  | D.P. | cc.  | D.P. | cc.  | D.P. | cc.  | D.P. |
|------|------|------|------|------|------|------|------|
| 10.0 | 50   | 12.8 | 39   | 17.2 | 29   | 26.3 | 19   |
| 10.2 | 49   | 13.2 | 38   | 17.8 | 28   | 27.8 | 18   |
| 10.4 | 48   | 13.5 | 37   | 18.5 | 27   | 29.4 | 17   |
| 10.6 | 47   | 13.9 | 36   | 19.2 | 26   | 31.3 | 16   |
| 10.9 | 46   | 14.3 | 35   | 20.0 | 25   | 33.3 | 15   |
| 11.1 | 45   | 14.7 | 34   | 20.8 | 24   | 35.7 | 14   |
| 11.4 | 44   | 15.2 | 33   | 21.7 | 23   | 38.5 | 13   |
| 11.6 | 43   | 15.6 | 32   | 22.7 | 22   | 41.7 | 12   |
| 11.9 | 42   | 16.1 | 31   | 23.8 | 21   | 45.5 | 11   |
| 12.2 | 41   | 16.7 | 30   | 25.0 | 20   | 50.0 | 10   |
| 12.5 | 40   |      |      |      |      |      |      |

#### *Preparation of Soluble Starch.*

Purified potato starch is digested with HCl (Sp. Gr. 1.037) at 60°F. for seven days, stirring each day; 1 lb. starch and 1,000 cc. dilute acid in a two-litre bottle are convenient quantities. It is washed very thoroughly by decantation, at first with tap water, and afterwards with distilled water, until the washings are free from chloride and are neutral. It is



collected on a filter-paper in a Büchner funnel, sucked as dry as possible, and dried on a porous plate at 110°F. as rapidly as possible. When dry it is triturated in a mortar and rubbed through a fine hair sieve.

*Starch solution.* For the diastatic activity the starch is dissolved in boiling distilled water, and 2 grm. made up to 100 cc. It should be perfectly mobile (not gelatinous) indicating perfect conversion into soluble starch; 10 cc. should not reduce more than 0.1 cc. of Fehling's solution.

The distilled water used in making up the starch solution must be pure and free from  $\text{NH}_3$ ,  $\text{HNO}_2$  (frequently present in commercial distilled water) which appreciably influence the diastatic conversion. (An alkalinity = 1 cc. N/10 acid per litre lowers the diastatic activity by 4°.)

### Cold Water Extract

25 grm. of ground malt are digested with 250 cc. of distilled water containing 20 cc. of N/10 ammonia for three hours at 70°F., stirring 3 or 4 times during this period. After filtering, the Sp. Gr. of the bright filtrate is taken at 60°/60°F. The excess of the Sp. Gr. over that of water (= 1000) divided by 3.86 and multiplied by 10, gives the cold water extract per cent.

The percentage of ready-formed soluble carbohydrates may be ascertained approximately by subtracting 4 from the value obtained for the cold water extract (C.W.E.) per cent.

| Sp. Gr. of<br>10 per cent. C.W.E. | C.W.E. per cent. | Sp. Gr. of<br>10 per cent. C.W.E. | C.W.E. per cent. | Sp. Gr. of<br>10 per cent. C.W.E. | C.W.E. per cent. |
|-----------------------------------|------------------|-----------------------------------|------------------|-----------------------------------|------------------|
| 1005.0                            | 12.9             | 1007.3                            | 18.9             | 1009.5                            | 24.6             |
| .1                                | 13.2             | .4                                | 19.1             | .6                                | 24.8             |
| .2                                | 13.4             | .5                                | 19.4             | .7                                | 25.1             |
| .3                                | 13.7             | .6                                | 19.6             | .8                                | 25.3             |
| .4                                | 14.0             | .7                                | 19.9             | .9                                | 25.6             |
| .5                                | 14.2             | .8                                | 20.2             | 1010.0                            | 25.9             |
| .6                                | 14.5             | .9                                | 20.4             | .1                                | 26.1             |
| .7                                | 14.7             | 1008.0                            | 20.7             | .2                                | 26.4             |
| .8                                | 15.0             | .1                                | 20.8             | .3                                | 26.6             |
| .9                                | 15.2             | .2                                | 21.2             | .4                                | 26.9             |
| 1006.0                            | 15.5             | .3                                | 21.5             | .5                                | 27.2             |
| .1                                | 15.8             | .4                                | 21.7             | .6                                | 27.4             |
| .2                                | 16.0             | .5                                | 22.0             | .7                                | 27.6             |
| .3                                | 16.3             | .6                                | 22.2             | .8                                | 28.0             |
| .4                                | 16.5             | .7                                | 22.5             | .9                                | 28.2             |
| .5                                | 16.8             | .8                                | 22.8             | 1011.0                            | 28.5             |
| .6                                | 17.1             | .9                                | 23.0             | .1                                | 28.7             |
| .7                                | 17.3             | 1009.0                            | 23.3             | .2                                | 29.0             |
| .8                                | 17.6             | .1                                | 23.5             | .3                                | 29.2             |
| .9                                | 17.8             | .2                                | 23.8             | .4                                | 29.5             |
| 1007.0                            | 18.1             | .3                                | 24.0             | .5                                | 29.7             |
| .1                                | 18.3             | .4                                | 24.3             | .6                                | 30.0             |
| .2                                | 18.6             |                                   |                  |                                   |                  |



## Statement of Results.

The results are expressed to the nearest first decimal place only, except in the cases of diastatic activity, which is recorded to the nearest integer, and are stated according to the following scheme:—

Extract in brewers' lbs. per standard quarter

Moisture, per cent.

Diastatic activity (Lintner value).

Tint (10 per cent. wort, 1 in. cell, "52" series Lovibond).

Cold water extract, per cent.

Ready-formed soluble carbohydrates, per cent.

## COLOURED MALTS.

As in the case of pale malts, the "Seck" or "Boby" mills (set at 0.5 mm.) should be used in the analysis of brown and crystal malts.

With black barleys and malts the character of the grind is not of such importance, for the extract of a black barley or malt is the same whether ground at seck 0.5 mm. or more finely in another type of mill. The use of a coffee mill, set close so as to obtain a fine grind, is recommended for grinding a black barley or malt.

Black malts and barleys, and brown and crystal malts are not commonly purchased on the basis of the standard quarter of 336 lb., various weights and measures being employed. For convenience of comparison, however, it is recommended that analytical results relating to such malts and barleys should be expressed in terms of pounds per excise standard quarter of 336 lbs.

### Brown and Crystal Malts.

*Extract.* 50 gm. of the ground sample (seck 0.5 mm.) is mashed with 300 cc. of distilled water at 158°F., and when constant at 150°F., 100 cc. of cold water extract of malt previously heated to 150°F. is added. The mixture is kept at 150°F. for 1 hour, cooled to 60°F., diluted to 515 cc., shaken, filtered, and the Sp. Gr. taken. The necessary correction for the cold water extract of malt employed is obtained by diluting 100 cc. of the malt extract with 300 cc. of water, the mixture being kept at 150°F. for 1 hour, subsequently cooled (60°F.), made up to 500 cc., filtered, and its Sp. Gr. taken.

Sp. Gr. of mash — Sp. Gr. of C.W. extract of malt  
= Sp. Gr. due to malt alone.

Extract of brown, etc., malt

= Sp. Gr. due to malt  $\times 3.36$  brewers' lbs. per  
quarter of 336 lbs.

**Cold Water Extract of Malt.** The extract is prepared from a well modified pale malt of diastatic power  $30^{\circ}$ – $40^{\circ}$  (Lintner) by digestion with 3 times its weight of distilled water for 1 hour at  $60^{\circ}$ – $70^{\circ}$  F. and subsequent filtration.

**Colour.** 20 cc. of the above extract is diluted to 100 cc. and the colour read in a 1 in. cell. The colour due to the malt extract is neglected.

### Black Barleys and Malts.

**Extract.** 50 grm. of the ground sample (coffee mill used) is extracted with about 350 cc. boiling distilled water, stirring well to prevent balling. The infusion is kept in a boiling water-bath for 1 hour, after which it is cooled, diluted to 515 cc. ( $60^{\circ}$  F.), shaken, filtered through an open-textured filter paper, and the Sp. Gr. of the filtrate taken.

Extract = Sp. Gr.  $\times$  3.36 brewer's lbs. per quarter.

**Colour.** 20 cc. of the above filtrate, which must be brilliant, is diluted to 1000 cc., and the colour read in a 1 in. cell.

### Caramel.

**Colour.** 10 grm. is dissolved in water and diluted to 100 cc. 10 cc. of this solution is diluted to 1000 cc., filtered if necessary, and the colour read in a 1 in. cell.

## STATEMENT OF RESULTS.

The results are expressed to nearest first decimal only, except in the case of tint, which is recorded to the nearest half unit.

### Brown and Crystal Malts.

Extract per standard quarter of 336 lbs.

**Colour.** In 1 in. cell. "52" series, Lovibond (2 per cent. extract).

### Black Barleys and Malts.

Extract per standard quarter of 336 lbs.

**Colour.** 1 in. cell. "52" series, Lovibond (0.2 per cent. extract).

### Caramel.

**Colour.** 1 in. cell. "52" series, Lovibond (0.1 per cent. solution).

(In commercial practice many caramels have their colour expressed *on the caramel*. This figure is obtained by multiplying the colour of the 0.1 per cent. solution by 1000.)

## Time of Saccharification.

In addition to the "Committee" determinations, a commercial statement of the analysis of a sample of malt very often contains a figure known as the "Time of Saccharification."

10 gram. of ground malt is mashed with 100 cc. water at 155°F., and maintained at 150°F. After 10 minutes the mixture is stirred and allowed to settle somewhat. Several cc. of the wort are withdrawn and tested with iodine solution for starch, this being repeated every 5 minutes until conversion of the starch is complete. It frequently happens that starch nearly disappears after, for example, 30 minutes, but that a small quantity persistently remains for a considerable time longer.

The following determinations, though not included in a commercial analysis, are sometimes required.

### "Dry Extract."

100 cc. of a solution containing 1 gram. dry malt extract weighs 100.40 gram., i.e., 1 gram. malt extract weighs 0.4 gram. when in solution.

Hence dry weight of malt extract in 100 cc. = (weight of 100 cc. - 100)/0.4 = 10 gram. malt.

and dry weight of extract from 1 quarter malt (336 lbs.)  
 = (weight of 1,000 cc. - 1,000)/0.4  $\times$  3.36.  
 = ordinary brewers' extract/0.4,  
 = brewers' extract  $\times$  2.5.

### Calculation of "Grains."

1 quarter malt with  $x$  per cent. water =  $336 - 3.36x$  dry solids.

Dry weight of extract from 1 quarter =  $y$

Hence weight of dry "grains" from 1 quarter malt (336 lbs.)  
 =  $(336 - 3.36x) - y$ .

### Non-Coagulable Proteins.

25 gram. ground malt is digested with 250 cc. distilled water at 60°F. for 3 hours, stirring occasionally, the mash is filtered bright and 100 cc. boiled for 20 minutes, again made up to 100 cc., filtered, and 10 cc. (= 1 gram. malt) of filtrate taken for a Kjeldahl determination, using 10 cc. acid and 5 gram.  $\text{KHSO}_4$ .

$N \times 6.3$  = non-coagulable protein.

As some analysts use the factor 6.25, it is advisable to state the factor used in a statement of results.

## Malt Worts.

For analysis of malt worts see under "Wort Analysis."

### PHYSICAL EXAMINATION.

The chemical examination must be supplemented by a careful physical examination, noting:—

1. The extent of acrospire growth. This should be  $\frac{2}{3}$  to  $\frac{3}{4}$  the length of the corn, and the more uniform the better the sample.

2. The presence or absence of mould.

3. The presence of damaged or half corns.

4. Any corns attacked by weevil.

5. "Brightness." The brightest malts are sometimes those worst prepared. Malts from kiln-dried barleys are usually of poorer colour than those made direct. Thorough withering generally means loss of colour.

6. Flavour. Sweet tasting malts are suspicious. Under-cured malts have a "pasty" flavour and also a peculiar bitterness, detected only after thorough mastication.

7. The appearance of sections cut in the farinator. Well modified corns have a mealy, and hard corns a vitreous appearance.

### INTERPRETATION OF RESULTS.

1. *Moisture* may be as low as 0.5 when malt is fresh from the kiln, but rapidly increases to 1.5 per cent., and in a properly stored malt will not exceed 2.5—3 per cent. A malt with excess of water (say over 3 per cent.) is said to be "slack," and if the moisture is above 3.5 per cent. certainly requires re-drying before use, although re-drying does not entirely recover a malt which has once become "slack." Contracts generally specify delivery at brewery at a maximum of 3 per cent. This means leaving the malting at a maximum of 2.5 per cent., as the average moisture absorbed in transit is 0.5 to 0.7 per cent.

2. *Extract*. This figure is a measure of the amount of beer the brewer can produce from the malt, and naturally the higher this figure the better. However, it must be remembered that both a poor quality malt and a high quality malt may both yield equally high extracts, but the quality of such extracts will be decidedly different. The quality of the extract is determined partly by the remaining analytical data, partly by the physical examination and the district in which the barley was grown. Malts from foreign barley usually give 3–4 per cent. less extract than those from English barley.

3. *Tint*. It is generally not desirable to use a malt paler than 3.5° (on 10 per cent. wort), as a danger from under-curing then becomes probable; but even for pale beers it is

not necessary to use a malt paler than 4°. High tints point to higher temperatures on the kiln and the possibility of further crippled diastase.

4. *Cold water extract* (C.W.E.), *soluble non-coagulable protein*, and *ready-formed sugars* (R.F.S.).

These figures are a guide as to whether the malt has been forced, and it is generally agreed that high C.W.E. indicates defective manufacture. Forced malts produce a wort with excess of assimilable nitrogen, which gives a "thin" beer of low stability. The C.W.E. indirectly indicates the amount of non-coagulable nitrogen, and this is proportional to the assimilable nitrogen. Briant gives the maximum soluble non-coagulable protein as 2.6 per cent. H. Brown states that there is no increase of assimilable nitrogen during drying on the kiln, but that the R.F.S. rise considerably at this stage. Briant has drawn attention to exceptions.

5. *Diastatic activity*. The following are intended as guides and not rigorous standards:

*Mild and black beers*. The malt should have D.A. 24°–32°.

*Pale ales*. D.A. 32°–42°.

6. *Time of Saccharification* (T.S.).

This figure has lost favour somewhat, owing to the indefinite end-point with iodine under the conditions of the test.

Briant gives the following as a guide:

- |                                  |                            |
|----------------------------------|----------------------------|
| i. Extremely well modified malts | T.S. = 25 minutes or less. |
| ii. Average modification         | T.S. = 25–35 minutes.      |
| iii. Poor                        | T.S. = 45 "                |
| iv. Bad                          | T.S. = over 45 "           |

The test in its present form is not suitable for including in a malt analysis, but many commercial analyses include this figure, although not recommended by the Malt Analysis Committee.

#### SPECIMEN ANALYSES OF MALT.

|                   | Californian. |              | Chilian | Ouchac | Australian<br>Chevalier | English<br>Pale Ale<br>Malt | English Mild |              |
|-------------------|--------------|--------------|---------|--------|-------------------------|-----------------------------|--------------|--------------|
|                   | 1st<br>Qual. | 2nd<br>Qual. |         |        |                         |                             | 1st<br>Qual. | 2nd<br>Qual. |
|                   | 1922         | 1922         | 1921    | 1913   | 1920                    | 1922                        | 1922         | 1922         |
| Moisture % .. ..  | 1.2          | 1.5          | 1.6     | 2.7    | 2.9                     | 1.6                         | 1.2          | 1.6          |
| Extract .. ..     | 92.4         | 90.7         | 91.9    | 91.5   | 93.7                    | 98.4                        | 97.8         | 94.4         |
| Colour (10% wort) | 4.5          | 4.5          | 4.0     | 5.0    | 5.5                     | 4.5                         | 8.0          | 8.0          |
| C.W.E. % .. ..    | 18.8         | 19.9         | 19.8    | 19.1   | 19.0                    | 19.9                        | 20.6         | 19.6         |
| R.F.S. % .. ..    | 14.8         | 15.9         | 16.1    | 15.1   | 15.0                    | 15.9                        | 16.6         | 15.6         |
| D.A. .. ..        | 34           | 34           | 40      | 44     | 33                      | 37                          | 36           | 36           |

### 3. Flaked Maize or Rice.

Determinations required are the brewing extract, moisture, and oil, and occasionally proteins ( $= N \times 6.3$  or  $6.25$ ), and starch. See "Carbohydrates."

*Extract.* For this determination a cold water extract of malt is necessary, which is prepared as follows:

A tender, well-modified malt of D.P.  $> 30^\circ$  is extracted with three times its weight of distilled water for one hour at  $60^\circ$ – $70^\circ$  F. and subsequently filtered.

20 grm. flaked material is mixed with 120 cc. distilled water and the temperature adjusted to  $160^\circ$  F. 50 cc. of the above cold water extract are then added, the mixture well stirred, covered with a watch glass and kept at  $150^\circ$  F. for two hours, after which the whole mash is washed through a large funnel into a 200 cc. flask, cooled to  $60^\circ$  F., and diluted to the mark. The flask is well shaken, the contents filtered through a dry filter paper, and the Sp. Gr. of the filtrate determined with Sp. Gr. bottle or Sprengel tube.

50 cc. of cold water extract is treated exactly as the above, omitting the flakes. After two hours the extract is washed into a 200 cc. flask, cooled, diluted to the mark, filtered through dry filter paper, and the Sp. Gr. of the filtrate taken.

Sp. Gr. of maize extract and cold water extract =  $x$

„ „ cold water extract =  $y$

„ „ maize extract =  $x - y$

Extract in brewer's lbs. from 336 lbs. maize =  $(x - y) 3.32$ .

$(3.32 = 3.36 \times \frac{200}{202.5})$  is used, as it is necessary to allow 2.5 cc. for the volume occupied by the cellulose, etc.)

*Moisture.* 5 grm. are dried for 5 hours in a boiling water oven. The loss of weight is taken as moisture.

*Oil* is determined by extracting the flaked material with ether for six hours, after soaking overnight, in a Soxhlet apparatus.

#### INTERPRETATION OF ANALYSIS OF FLAKED MATERIALS.

Immediately on manufacture the moisture is reduced to 4 per cent., but rapidly rises, and is seldom below 6 per cent. on delivery at the brewery.

|          | Maize Flakes. | Rice Flakes. |
|----------|---------------|--------------|
|          | per cent.     | per cent.    |
| Starch   | $> 75$        | $> 80$       |
| Fat      | $< 1.3$       | $< 0.5$      |
| Proteins | $< 10$        | $< 8.5$      |
| Moisture | $< 8$         | $< 8$        |



Flaked oats give an average extract of 88.5 brewer's lbs. per quarter.

Malted oats give an average extract of 70—76 brewer's lbs. per quarter.

### Composition of Flaked Grains (L. Briant).

|           | Rice.  | Maize. | Barley. |
|-----------|--------|--------|---------|
| Starch    | 81.63  | 76.40  | 72.31   |
| Oil       | 0.20   | 1.30   | 1.72    |
| Proteins  | 8.73   | 9.82   | 10.35   |
| Ash       | 0.37   | 0.45   | 2.35    |
| Moisture  | 7.90   | 7.50   | 5.82    |
| Cellulose | 1.17   | 4.53   | 7.45    |
|           | 100.00 | 100.00 | 100.00  |

## 4. Raw Grain.

This includes maize grits, rice grits, barley.

*Extract.* 20 gm. of the well-ground sample are brought into a beaker, and 110 cc. cold water added together with 5 cc. of cold water extract of malt (prepared as under "Flaked grain"). The beaker and contents are slowly heated up to boiling point in a water-bath to gelatinise the starch. During this time the contents must be continually stirred; the boiling is continued for one hour, after which the contents are cooled to 160°F., and 45 cc. of the cold water extract added (giving a total of 50 cc.). The whole is allowed to stand 2 hours at 150°, and then cooled to 60°F., washed into a 200 cc. flask and diluted to the mark. The Sp. Gr. of the clear filtrate is taken =  $S_1$ .

The cold water extract correction is determined by digesting 50 cc. with 100 cc. water by the side of the above for 2 hours at 150°F., making up to 200 at 60°F., and taking the Sp. Gr. of the clear filtrate =  $S_2$ .

Brewers' extract in lbs. (brewers) per 336 lbs. of grits  
 $= 3.32 \times (S_1 - S_2)$ .

*Oil* is determined as under "Flaked grain."

*Moisture* is determined by drying 5 gm. for 5 hours in the hot-water oven.

*Mineral matter*, if necessary, by careful ignition in Pt dish, finally igniting more strongly to a white ash.

*Proteins.* By Kjeldahl.  $N \times 6.25$  or 6.3.



## Composition of Maize and Rice Grits (Briant).

|                 | Maize Grits. | Rice Grits. | Barley. |
|-----------------|--------------|-------------|---------|
| Oil             | < 1%         | < 0.4%      | < 2.5%  |
| Water           | < 14%        | < 14%       |         |
| Extract         | 96-100       | 103         | 88      |
| Starch          | 74%          | 79%         |         |
| Proteins        | 8%           | < 7.5%      | < 12.5% |
|                 | Maize Grits. | Rice Grits. |         |
| Starch          | 73.80        | 79.19       |         |
| Oil             | 0.82         | 0.80        |         |
| Proteins        | 9.05         | 8.91        |         |
| Ash             | 0.40         | 0.30        |         |
| Moisture        | 10.85        | 10.30       |         |
| Cellulose, etc. | 5.08         | 0.50        |         |

## 5. Malt Extract.

### 1. *Free Maltose.*

The copper oxide from 20 cc. of a 2 per cent. solution is determined by the Brown, Morris and Millar method as under "Sugars."

250 cc. 10 per cent. solution + 2 gm. of washed pressed yeast are allowed to ferment at about 26° C. until fermentation is complete (usually not less than 48 hours), after which the solution is heated to boiling for about half an hour on the water-bath to remove alcohol; a small amount of alumina cream is added to aid clarification, and the whole made up to 250 cc. again and filtered. The Cu reducing power is determined on a suitable quantity, say 20 cc., but this requires trial, and the maltose obtained from the CuO on reference to the table.

Maltose before fermentation — maltose after fermentation  
= maltose present in the free condition and as very low type maltodextrins (*i.e.* rich in maltose).

### 2. *Maltose present as maltodextrins.*

This is given by the maltose found after fermentation, as in (1), but must previously be corrected for the CuO determined under (4) below.

### 3. *Dextrin present as maltodextrins.*

To 200 cc. of the fermented solution from (1) is added 10 cc. of malt extract (prepared by soaking 400 gm. of ground malt with 1000 cc. distilled water at about 15.5°C. (60°F.), containing 5 cc. of chloroform, for at least 5 hours, straining off the malt and filtering bright; this will keep for about 14 days in a stoppered bottle without decomposing; it must be rejected on turbidity appearing), and the mixture digested at 55°C. (131°F.) for 1 hour. Maltodextrins are converted into free maltose.

The correction for the malt extract is determined by adding 5 cc. to 100 cc. water and treating as above.

The two solutions are heated to boiling for about half an hour and diluted to 200 cc. and 100 cc. respectively. The Cu reduction is determined on suitable quantities of the filtrates, say 10 cc., and the maltose equivalent to each determined from the table.

Maltose in converted solution — maltose due to malt extract — maltose before conversion, found in (2) = maltose produced by diastase in the malt extract from the dextrin of the maltodextrin.

$$\text{Dextrin} = \text{maltose} \times \frac{180}{198}$$

#### 4. Stable dextrin.

150 cc. of the degraded conversion from (3) are fermented with about 1.5 gm. of washed pressed yeast at 26° C. (79° F.) for about 48—72 hours, after which the solution is heated at the boil for about half an hour to expel alcohol, cooled, and made up to 150 cc. The solution is filtered and the polarimeter reading taken (in circular degrees).

100 cc. of this fermented solution are completely fermented with 5 cc. of malt extract and 1 gm. of pressed yeast at 26° C. (79° F.).

A "blank" is carried out on 100 cc. water, 5 cc. malt extract, and 1 gm. yeast. In presence of diastase (in the malt extract) the stable dextrin is fermented away by the yeast, although neither agent alone is capable of attacking this dextrin.

The fermented conversion and the blank after fermentation are both kept at boiling point for about half an hour to expel the alcohol, cooled, and both are made up to 100 cc., using a small amount of alumina cream for clarification. The optical rotations and Cu reductions are determined on the filtrates.

The rotation of the blank is deducted from that of the actual test and the stable dextrin calculated from the loss of rotation on fermentation with diastase and yeast.

Rotation in 2 dm. tube before fermentation with diastase and yeast =  $x$

Rotation in 2 dm. tube after fermentation with diastase and yeast =  $y$

Rotation of blank in 2 dm. tube after fermentation with diastase and yeast =  $z$

$$\text{Loss in rotation} = x - (y - z).$$

1 gm. dextrin in 100 cc. solution gives a reading of  $a$  in 2 dm. tube.

$$202 = \frac{a \times 100}{2 \times 1} \quad a = \frac{202}{100} \times 2 = 4.04.$$

Stable dextrin in 100 cc. of solution =  $x - (y - z) / 4.04$   
from which the percentage in the malt extract is calculated.

The CuO due to the fermented conversion less that due to the cold water extract of malt ("diastase") used is required for making the correction in (2).

#### 5. *Diastatic activity.*

Some malt extracts contain no diastase as it has been killed in their preparation; others, however, contain diastase and are then known as diastatic malt extracts; in these latter the D.A. is determined exactly as under malt analysis, but generally the D.A. is very high, therefore less of the extract must be allowed to act on the starch solution.

#### 6. *Protein.*

Determined by the Kjeldahl method as under "Malt analysis."

#### 7. *Moisture.*

The excess specific gravity of a 10 per cent. solution over 1000 is divided by 4.0, which gives total solids in 100 cc.; this multiplied by 10 gives the apparent total solids percentage. This figure should be corrected for the ash as under "Moisture in Sugar," to give the real total solids percentage.

Moisture percentage =  $100 - \text{real total solids percentage}$ .

#### 8. *Ash.*

By careful ignition of about 5 gm. in a platinum dish.

A. R. Ling (*Analyst*, 1904, **29**, 244) has pointed out that dextrose is present in genuine malt extract; this sugar is determined as glucosazone and the necessary corrections made in the figures obtained in the foregoing determinations.

### SPECIMEN ANALYSES OF MALT EXTRACTS (A. R. Ling).

|  | I.      | II.     | III.  | IV.   | V.      | VI.     |
|--|---------|---------|-------|-------|---------|---------|
| Sp. gr. 15.5/15.5° ..                      | 1395.70 | 1395.12 | —     | —     | 1408.43 | 1377.82 |
|  | %       | %       | %     | %     | %       | %       |
| Maltose (apparent) ..                      | 31.1    | 30.9    | 24.8  | 27.4  | 34.2    | 25.2    |
| Dextrose .. .. .                           | 17.2    | 18.2    | 22.0  | 19.1  | 12.5    | 20.0    |
| Dextrin (apparent) ..                      | 9.8     | 8.6     | 10.0  | 9.8   | 9.9     | 6.7     |
| Unfermentable matter<br>(as dextrin) .. .. | 4.5     | 3.5     | 8.9   | 5.8   | —       | —       |
| Ash .. .. .                                | 1.45    | 1.49    | 1.58  | 1.64  | 1.34    | 1.64    |
| Water .. .. .                              | 24.30   | 24.67   | 27.36 | 24.84 | 24.38   | 29.52   |
| Diastatic activity ..                      | 30.8    | 27.2    | 32.3  | 25.6  | 39.2    | 46.5    |
| S.R.P. $[\alpha]_D$ .. ..                  | 91.8    | 90.5    | 84.2  | 86.8  | 94.5    | 81.1    |

When the total copper reduced, less that due to dextrose, is calculated to maltose, the "apparent maltose" is obtained. The total polarimetric reading less that due to "apparent maltose" and dextrose gives the "apparent dextrin."

## 6. Caramel.

### 1. *Colouring power.*

This is determined by the standard method of "The Institute of Brewing Committee on Coloured Malts and Caramel, 1910," given under "Malt analysis."

### 2. *Loss of colour on fermentation.*

25 cc. of 10 per cent. caramel solution + 25 cc. wort or malt extract (Sp. Gr. about 1050—1060) are fermented with 1 gm. washed, pressed yeast at 26°C. for 48—72 hours, after which the whole is made up to 100 cc. and filtered. 10 cc. of the filtrate are diluted to 250 cc. and the colour read in a 1 in. or  $\frac{1}{2}$  in. cell as necessary. A correction can be made for the colour of the wort if desired, but never amounts to more than 1 unit, unless a very dark wort is employed, which is quite unnecessary, and is usually only 0.5. This reading is taken on the same strength solution as in (1), so that the difference gives the loss and is calculated to a percentage.

### 3. *Brewers' extract per 2 cwt.*

The Sp. Gr. of a 10 per cent. solution is taken and the excess over 1000 multiplied by 2.24.

### 4. *Fermentable matter.*

The Sp. Gr. of a 10 per cent. solution is taken. 125 cc. are fermented with 1–2 gm. well washed, pressed yeast for 48–72 hours at 26°C., after which the solution is made up to 250 cc., filtered to remove all yeast and 200 cc. evaporated down on the water-bath to about 70 cc. to remove alcohol, and washed into a 100 cc. flask and diluted to the mark. This solution will be equivalent to an original 10 per cent. solution, and on this solution the Sp. Gr. is taken, the loss of Sp. Gr. calculated to an original excess Sp. Gr. over 1000 of 100 gives the fermentable matter per cent.

### 5. *Proteins.*

By the usual Kjeldahl method, using 4–5 gm. caramel.

### 6. *Ash.*

By careful ignition of 4–5 gm. caramel in platinum dish.

### 7. *Moisture.*

By the method given under "Moisture in Sugar," making the usual correction for ash. The solution factor 3.86 is used.

### 8. *Action on bright beer.*

Bright beer is tinged to a deep tint with the sample, and the presence or absence of cloudiness or precipitate is observed both immediately and after standing a day or two.

### INTERPRETATION OF CARMEL ANALYSIS.

Caramels are prepared either from starch sugar (glucose) or from cane sugar; those from the latter probably give a richer flavour.

1. *Colour.* This varies considerably.

2. *Loss of colour on fermentation.* Some caramels show distinct loss, but good samples generally lose less than 4 per cent.

3. *Brewers' extract.* This is generally lower the higher the colour, but caramels of equal colour can show varying extracts, of which the higher is favoured by the brewer.

4. *Fermentable matter.* Most caramels show some fermentable matter, but an excessive amount shows imperfect preparation, undecomposed sugar remaining at the expense of colour.

5. *Protein.* To some extent this indicates the purity of the raw material used for preparation of the caramel; however, it must be remembered that 0.5 per cent. of sodium or ammonium carbonate is sometimes added to intensify the colour. Free  $\text{NH}_3$  or ammonium salts may be estimated by distillation with magnesia.

6. *Ash.* This also is some indication of purity of raw products, but if sodium carbonate has been used it will increase the ash.

7. *Moisture.* Liquid caramels frequently contain between 20-30 per cent. moisture.

8. *Action on bright beer.* Low grade caramels produce a cloud and precipitate when added to bright beer, the latter containing some of the colour, so that loss of colour results; but, apart from this, no caramel can be passed as satisfactory if it produces such cloud or precipitate.

The flavour is very important and is conveniently noted on the 10 per cent. solution. Some caramels have bitter flavours, but richness is generally associated with low colour. Particles of insoluble carbon are objectionable only in so far as they mean colour lost.

Caramels sometimes have a trace of liquorice added, especially those for black beers. A caramel should show neither very acid nor alkaline reaction.

## SPECIMEN ANALYSES OF CARAMELS (F. Robinson).

|                                | Beer.             | Caramel for |                | Stout.   |
|--------------------------------|-------------------|-------------|----------------|----------|
|                                |                   | Stout.      | Beer.          |          |
| Colour                         | 31000             | 17000       | 33000          | 26000    |
| Loss of colour on fermentation | 0%                | 0%          | 3%             | 0%       |
| Brewers' extract per 224 lbs.  | 62.4              | 67.3        | 65.5           | 62.9     |
| Fermentable matter             | 20.1%             | 24.7%       | 14.3%          | 16.5%    |
| Protein                        | 2.18%             | 1.92%       | 1.41%          | 1.82%    |
| Ash                            | 3.0%              | 2.18%       | 3.34%          | 2.80%    |
| Moisture                       | 30.8%             | 24.4%       | 27.6%          | 30.1%    |
| Flavour                        | v slightly bitter | sweet       | slightly sweet | pleasant |
| Beer, cloud                    | nil               | nil         | v. slight      | nil      |
| precipitate                    | small, pale       | v. small    | fair, pale     | v. small |

## 7. Hops.

Analysis does not as yet play a very important part in the valuation and use of hops, the chief method by which they are valued being the personal. The following determinations may be made :

1. *Moisture.*

Determined on 3-5 grm. by drying in boiling water oven for 5 hours. Some or all of the essential oil is also removed, but it does not exceed 0.5 per cent., so that the error is not very great, and the results are sufficient for technical requirements.

Drying over sulphuric acid *in vacuo* is preferable.

2. *Resins.*

These have been separated into three substances :

|                                   |   |
|-----------------------------------|---|
| $\alpha$ -Resin or humulone.      | } = Soft resins (soluble in petroleum ether). |
| $\beta$ -Resin or lupulinic acid. |   |
| $\gamma$ -Resin.                  | = Hard resin (insoluble in petroleum ether).  |

*Soft resins.* Determined by extracting about 3-4 grm. hops with petroleum ether, b.pt. 125-130° F., for about 24 hours in a Soxhlet apparatus and drying the extracted resins to constant weight in the hot water oven.

*Hard resin.* After extraction with petroleum spirit, as above, to remove soft resins, the hops are extracted with ether for about 12 hours. The extracted hard resin is dried to constant weight in hot water oven.



### 3. *Foreign matter.*

Determined by carefully picking out from a 50 gm. sample and weighing. The resins are determined on the whole hop flower so that foreign matter has to be considered together with resin in valuing the hops.

### 4. *Sulphur.*

This is introduced in one of two ways :—

- i. The growing hop is sprayed with finely-divided sulphur to prevent mould.
- ii. The hops are treated with sulphur during kilning when sulphur dioxide is formed and taken up by the hops.

i. To detect free sulphur. 5 gm. hops are boiled with 250 cc. water and 5 gm. pure slaked lime for 20 minutes. The liquid is cooled, filtered and tested immediately with dilute sodium nitroprusside solution. Red colour indicates sulphide, and hence free sulphur in the hops. The colour reaction may be made quantitative.

ii. To detect sulphur dioxide. The hops are treated with Zn and HCl. Any sulphur dioxide is converted into hydrogen sulphide and is passed into lead acetate solution. The PbS precipitated may be determined gravimetrically.

(5) *Tannin.* Originally tannin was considered to be of value in precipitating the proteins of the wort and that its percentage decreased with increase in age of the hop. A. C. Chapman, using his cinchonine method of estimation (*Journ. Inst. Brew.*, 1907, p. 646, and 1909, p. 360), has shown that the tannin percentage gives no valuable information of the brewing quality of the hop. Briant and Meacham hold the same opinion.

On the Valuation of the Antiseptic Properties of Hops the following papers may be consulted :—

A. Brown and G. Ward (*Journ. Inst. Brew.*, p. 641, 1910).

A. Brown and D. Clubb (*Journ. Inst. Brew.*, p. 261, 1913).

## RESULTS OF ANALYSIS OF HOPS.

*Moisture.* The amount should not exceed 10 per cent., or the hop will not keep well on storage. 8-9 per cent. is preferable.

*Sulphur.* Many brewers have great objection to sulphured hops because it disguises their real character; on the other hand, a sulphured hop generally keeps better than an unsulphured one, and the practice has not definitely been proved to be injurious. It is said that when sulphur is



sprinkled after the flower has developed it produces a peculiar smell in the dried hop which is strongly objected to, and yeast difficulties have with good reason been ascribed to heavily sulphured hops. Sulphur treatment in kilning is rarely practised abroad, but is very general in this country.

*Resins.* The soft resins are generally valued as preservatives, but hard resin is said to have no such action. As the hops are stored, the soft resins diminish and the hard resin increases; these changes are hastened by high temperature and high moisture content, chiefly by the former. Below 40°F. hops may be stored for a year with very little change in the resin values.

Briant gives the following analyses :

| Growth of Hops.   | Hard Resins.<br>Per cent. | Soft Resins.<br>Per cent. |
|-------------------|---------------------------|---------------------------|
| East Kent         | 3.91                      | 10.65                     |
| Sussex            | 5.30                      | 9.12                      |
| Worcester         | 5.12                      | 7.60                      |
| Goldings          | 4.25                      | 11.23                     |
| Californian       | 8.45                      | 12.20                     |
| Bavarian          | 8.20                      | 11.30                     |
| British Columbian | 8.55                      | 12.30                     |
| Hallertauer       | 7.60                      | 11.90                     |

## WORT AND BEER.

F. ROBINSON, M.Sc.Tech., B.Sc., F.I.C.

### Analysis of Malt Wort.

#### I. Malt Wort.

This is prepared in a similar way to the hot water extract under malt analysis. The analysis generally aims at determining the result of the digestion of the starch; however, the fact that malt yields to cold water bodies showing reducing power and optical activity makes correction for these necessary.

A 10 per cent. cold water extract is first prepared by extracting 25 grm. of the ground sample with 250 cc. water at 60°C. for 3 hours. The following determinations are made on the bright filtrate :

1. Ready-formed sugars. (See "Malt analysis.")
2. Copper reducing power on 20 cc. by Brown, Morris and Millar's method. (See "Sugar analysis.")
3. Optical rotation.

A 10 per cent. hot water mash is prepared as under "Malt analysis." The bright filtrate (wort) is used for the following determinations :

1. Sp. Gr., excess of which over  $1000 \div 3.86 =$  solids in 100 cc. (Some analysts use the factor 4.0.)
2. Copper reducing power on 20 cc.
3. Optical rotation.  
(Decolorisation may be necessary; to 50 cc. wort are added a few drops of lead basic acetate solution and alumina cream, diluted to 100 cc. and filtered bright. The rotation is multiplied by 2 to correct for dilution).
4. Protein by Kjeldahl.
5. Ash by ignition.

The maltose is obtained from the CuO values by the table, and the maltose in hot water extract is corrected for the sugars calculated as maltose in the cold water extract. From this the maltose in 100 cc. wort due to starch conversion is found = M.

If M grm. maltose in 100 cc. solution read in a 2 dm. tube give a rotation of  $\alpha$ .

$$138 = \frac{\alpha \times 100}{2 \times M} ; \quad \alpha = \frac{138 M \times 2}{100} = 2 \times 1.38 M$$

The optical rotation in a 2 dm. tube of the hot extract (wort) is corrected for that due to the cold extract, and from the result (R) the reading due to maltose is deducted, giving :  
The reading due to dextrin in 2 dm. tube =  $R - (2 \times 1.38 M)$ .

If 1 per cent. dextrin solution in 2 dm. tube gives a reading of A :

$$202 = \frac{A \times 100}{2 \times 1} ; \quad A = \frac{202 \times 2}{100} = 4.04$$

$$\text{Grams dextrin in 100 cc. wort} = \frac{R - (2 \times 1.38 M)}{4.04.}$$

The total solids in 100 cc. wort having been determined, the maltose and dextrin are calculated to a percentage on the *dry solids* (not on the malt), so also are the other figures if their statement is necessary. By this means the composition of wort of different Sp. Gr. (*i.e.*, concentrations) can be compared.

The above method of analysis is similar to that proposed by Heron, but it ignores the malto-dextrins, which certainly play an important part in brewing.

### *Determination of Malto-dextrins and Stable Dextrin.*

These are determined by the method of Moritz and Morris, described in full under "Malt extracts."

The method may be somewhat shortened if stable dextrin is not required.

### *Determination of Malto-dextrins only*

The following example given applies to a wort of Sp. Gr. about 1030.

The following determinations are made :

- i. Copper reduction on 10 cc. of 20 per cent. wort, prepared by diluting 20 cc. of that at Sp. Gr. 1030 to 100 cc.
- ii. 25 cc. wort + 2.5 cc. diastase solution (i.e., cold water extract of malt prepared as under "Malt Extracts") are kept at 130°F. for 1 hour, cooled and diluted to 100 cc. The copper reduction on 10 cc. is determined. The CuO reduction for the diastase solution must be known, and the necessary correction made.
- iii. 50 cc. wort, after boiling to sterilise, is fermented with about 0.2 gm. washed, pressed yeast at 80°F. for 48 hours; alumina cream is added, and the mixture made up to 100 cc., filtered, and the copper reduction taken on 25 cc.
- iv. 50 cc. of boiled wort + 0.25 cc. diastase solution + 0.2 gm. yeast is allowed to ferment 48 hours at 80°F. In presence of diastase the yeast ferments away malto-dextrins and stable dextrin. Alumina cream is added to the fermented liquid, which is diluted to 100 cc., filtered, and the reducing power taken on 25 cc. of the filtrate. This gives the correction to be applied to (iii) before the combined maltose can be calculated. It will be seen that CuO due to the diastase solution is included in the correction, but the amount is negligible.

Maltose in malto-dextrin in 25 cc. wort =  $2[(iii) - (iv)]$ .

Dextrin in malto-dextrin in 25 cc. wort.

$$= 0.95 \left\{ 10 \text{ (ii, corrected for diastase)} - 12.5 \text{ (i)} \right\}$$

The figures (i)–(iv) represent quantities of *maltose* as determined under these headings from the CuO and maltose table.

D/M gives the malto-dextrin "type" or "ratio."

The malto-dextrin is calculated to a percentage of the dry solids in solution.

## II. Copper Wort.

This is the wort from the mash tun which is running into the boiling copper. The sample should always be taken after the same interval (generally 20 minutes) from the time of starting to run off the wort from the mash tun. The wort is boiled *immediately* to kill diastase and so prevent any further alteration in the starch conversion products.

The analysis is made either by Heron's method, as under "malt wort," when the corrections for cold water extract are required, or the wort is examined for malto-dextrins and stable dextrin by Moritz and Morris' method, in which corrections for cold water soluble bodies are not required. Moritz and Morris' method gives the most useful information.

The optical activity of the wort is frequently taken, and the specific rotatory power calculated on the dry solids as follows :

$$\text{S.R.P.} = \frac{\alpha \times 100}{l \times c}$$

$\alpha$  = optical rotation,

$l$  = length of observation tube in dm.

$c$  = concentration (gram. per 100 cc.) = excess Sp. Gr. over  $1000 \div 3.86$  (or 4.0, according to different authorities).

It is a useful guide in a series of mashings with the same composition of grist (malts, etc.).

### INTERPRETATION OF RESULTS.

Morris and Moritz give the following table of malto-dextrin types for the various worts of typical ales :

|                         | Family  | Stock   | Mild    |        | Pale |
|-------------------------|---------|---------|---------|--------|------|
|                         | Bitter. | Bitter. | Running | Stout. | Ale. |
|                         |         |         | Ale.    |        |      |
| Gravity                 | 1052.8  | 1066.7  | 1050    | 1075   |      |
| Maltose in maltodextrin | 4.15    | 3.75    | 4.70    | 10.00  |      |
| Dextrin „ „             | 7.24    | 7.44    | 4.66    | 8.30   |      |
| Total maltodextrin      |         |         |         |        |      |
| per cent. of solids     | 11.43   | 11.19   | 9.36    | 18.30  |      |
| Type                    | { 1 M   | 1 M.    | 1 M.    | 1 M.   | 1 M  |
|                         | { 1.7 D | 2 D.    | 1 D.    | 1 D.   | 2 D. |

The following is an example of a wort analysis according to Heron's method :—

| Substance.          | % of Wort Solids. |
|---------------------|-------------------|
| Maltose             | 48.62             |
| Dextrin             | 19.65             |
| Protein             | 4.80              |
| Ash                 | 1.65              |
| Ready formed sugars | 23.08             |
| Other substances    | 2.2               |
|                     | <hr/> 100 <hr/>   |

For a full discussion of the influence of the type of maltodextrins, which is very great and finds no indication in Heron's method, Moritz and Morris, "The Science of Brewing," may be consulted.

A point to note is that a beer does not contain the same type maltodextrin as the wort from which it was produced; for example, a pale ale wort gave a type  $\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \begin{smallmatrix} M \\ D \end{smallmatrix} \right.$ , but the beer gave  $\left\{ \begin{smallmatrix} 1 \\ 1 \end{smallmatrix} \begin{smallmatrix} M \\ D \end{smallmatrix} \right.$  (analysed immediately on "racking," i.e. filling into casks); during storage of the beer the type is still further lowered, and the (low type) maltodextrin destroyed by fermentation by the yeast.

## Analysis of Beer.

### 1. *Original gravity* (O.G.).

#### (a) Distillation method.

The original gravity of a beer may be described as the specific gravity of the wort, before fermentation, from which the beer was made.

For excise purposes this is determined by the distillation process, using the recent new tables of Sir T. E. Thorpe and H. T. Brown.

The sample of beer is filtered through a dry filter into dry beaker, keeping the filter covered with a clock glass. The distillation apparatus consists of a large flask connected by a wide leading tube (which slopes down towards the flask) with a vertical spiral condenser. Into the flask is measured 200 cc. of filtered beer, and distillation carried out until two-thirds of the liquid has passed over, collecting the distillate in a 200 cc. flask. After distillation the distillate is diluted to 200 cc., and its Sp. Gr. determined accurately.

1000 - Sp. Gr. = degrees spirit indication.

The residue in the distillation flask is also made up to 200 cc. again, and its Sp. Gr. accurately determined.

O.G. = residual gravity + gravity lost corresponding to spirit indication.

ORIGINAL GRAVITY TABLE, 1914 (T. E. Thorpe and H. T. Brown).

| Spirit<br>Indica-<br>tion. | Corresponding Degrees of Gravity Lost. |       |       |       |       |       |       |       |       |       |
|----------------------------|--|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                            | 0.0                                    | 0.1   | 0.2   | 0.3   | 0.4   | 0.5   | 0.6   | 0.7   | 0.8   | 0.9   |
| 0                          | 0.00                                   | 0.42  | 0.85  | 1.27  | 1.70  | 2.12  | 2.55  | 2.97  | 3.40  | 3.82  |
| 1                          | 4.25                                   | 4.67  | 5.10  | 5.52  | 5.95  | 6.37  | 6.80  | 7.22  | 7.65  | 8.07  |
| 2                          | 8.50                                   | 8.94  | 9.38  | 9.82  | 10.26 | 10.70 | 11.14 | 11.58 | 12.02 | 12.46 |
| 3                          | 12.90                                  | 13.34 | 13.78 | 14.22 | 14.66 | 15.10 | 15.54 | 15.98 | 16.42 | 16.86 |
| 4                          | 17.30                                  | 17.75 | 18.21 | 18.66 | 19.12 | 19.57 | 20.03 | 20.48 | 20.94 | 21.39 |
| 5                          | 21.85                                  | 22.30 | 22.76 | 23.21 | 23.67 | 24.12 | 24.58 | 25.03 | 25.49 | 25.94 |
| 6                          | 26.40                                  | 26.86 | 27.32 | 27.78 | 28.24 | 28.70 | 29.16 | 29.62 | 30.08 | 30.54 |
| 7                          | 31.00                                  | 31.46 | 31.93 | 32.39 | 32.86 | 33.32 | 33.79 | 34.25 | 34.72 | 35.18 |
| 8                          | 35.65                                  | 36.11 | 36.58 | 37.04 | 37.51 | 37.97 | 38.44 | 38.90 | 39.37 | 39.83 |
| 9                          | 40.30                                  | 40.77 | 41.24 | 41.71 | 42.18 | 42.65 | 43.12 | 43.59 | 44.06 | 44.53 |
| 10                         | 45.00                                  | 45.48 | 45.97 | 46.45 | 46.94 | 47.42 | 47.91 | 48.39 | 48.88 | 49.36 |
| 11                         | 49.85                                  | 50.35 | 50.85 | 51.35 | 51.85 | 52.35 | 52.85 | 53.35 | 53.85 | 54.35 |
| 12                         | 54.85                                  | 55.36 | 55.87 | 56.38 | 56.89 | 57.40 | 57.91 | 58.42 | 58.93 | 59.44 |
| 13                         | 59.95                                  | 60.46 | 60.97 | 61.48 | 61.99 | 62.51 | 63.01 | 63.52 | 64.03 | 64.54 |
| 14                         | 65.10                                  | 65.62 | 66.14 | 66.66 | 67.18 | 67.70 | 68.22 | 68.74 | 69.26 | 69.78 |
| 15                         | 70.30                                  | 70.83 | 71.36 | 71.89 | 72.42 | 72.95 | 73.48 | 74.01 | 74.54 | 75.07 |
| 16                         | 75.60                                  | -     | -     | -     | -     | -     | -     | -     | -     | -     |

(b) Evaporation method.

The Sp. gr. of the original beer is ascertained, after agitation to remove CO<sub>2</sub> as far as possible. A measured portion of the sample is evaporated to drive off the alcohol, then made up to the original volume, and the Sp. gr. taken. The difference in the two gravities gives the spirit indication, which is corrected as before for any excess acidity. The corresponding gravity lost is given by the table of Thorpe and Brown; this figure requires correcting by the addition of 1/40th of its value.

This method may be used as a check on the distillation process by including in the latter a determination of the Sp. gr. of the beer before distilling.

If the beer has become sour the original gravity as just determined is incorrect, because some of the alcohol has been converted into acetic acid. In such a case the sample should be neutralised before distillation and allowance made for the acidity. The authorities assume that normal beer contains 0.10 acid expressed as acetic acid; therefore after determina-



tion of acidity a deduction of 0.10 per cent. is made before calculating the correction. The official method of determining the acidity is by titration of the sample with N/10 alkali; the end-point is ascertained by means of litmus paper. Previous to titration the sample should be boiled for 2 minutes to expel  $\text{CO}_2$ , afterwards washing down the condenser into the beer.

Example :      Acidity =  $0.5\% - 0.1\% = 0.4\%$ .

From the table this = 0.52 degrees of spirit indication.

This is added to that previously found, *e.g.*, 9.5.

$$9.5 + 0.52 = 10.02,$$

and from the previous table this corresponds to  $45^\circ$  gravity loss.

Residual gravity 1015. Corrected O. G. = 1060.

#### ACIDITY OF BEER CALCULATED TO ACETIC ACID AND DEGREES OF SPIRIT INDICATION

| Excess<br>% acid. | 0    | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    |
|-------------------|------|------|------|------|------|------|------|------|------|------|
| 0.0               | —    | 0.02 | 0.04 | 0.06 | 0.07 | 0.08 | 0.09 | 0.11 | 0.12 | 0.13 |
| 0.1               | 0.14 | 0.15 | 0.17 | 0.18 | 0.19 | 0.21 | 0.22 | 0.23 | 0.24 | 0.26 |
| 0.2               | 0.27 | 0.28 | 0.29 | 0.31 | 0.32 | 0.33 | 0.34 | 0.35 | 0.37 | 0.38 |
| 0.3               | 0.39 | 0.40 | 0.42 | 0.43 | 0.44 | 0.46 | 0.47 | 0.48 | 0.49 | 0.51 |
| 0.4               | 0.52 | 0.53 | 0.55 | 0.56 | 0.57 | 0.59 | 0.60 | 0.61 | 0.62 | 0.64 |
| 0.5               | 0.65 | 0.66 | 0.67 | 0.69 | 0.70 | 0.71 | 0.72 | 0.73 | 0.75 | 0.76 |
| 0.6               | 0.77 | 0.78 | 0.80 | 0.81 | 0.82 | 0.84 | 0.85 | 0.86 | 0.87 | 0.89 |
| 0.7               | 0.90 | 0.91 | 0.93 | 0.94 | 0.95 | 0.97 | 0.98 | 0.99 | 1.00 | 1.02 |
| 0.8               | 1.03 | 1.04 | 1.05 | 1.07 | 1.08 | 1.09 | 1.10 | 1.11 | 1.13 | 1.14 |
| 0.9               | 1.15 | 1.16 | 1.18 | 1.19 | 1.21 | 1.22 | 1.23 | 1.25 | 1.26 | 1.28 |
| 1.0               | 1.29 | 1.31 | 1.33 | 1.35 | 1.36 | 1.37 | 1.38 | 1.40 | 1.41 | 1.42 |

Long supplies an instrument which determines the O.G. by observation of the present gravity and the scale reading of a sensitive thermometer placed in the boiling beer. The scale is graduated not in degrees of temperature but in degrees of gravity. The present gravity *plus* gravity reading on the scale gives the original gravity of the beer. The instrument has to be adjusted to zero by using distilled water before carrying out the determination. The instrument should be checked against the distillation method before use, and the correction noted. The instrument is very useful where a number of determinations are required, but in which extreme accuracy is not essential.

#### 2. Alcohol.

This is determined from the Sp. Gr. of the spirit from the original gravity determination by reference to the alcohol tables (see "Spirits" section). If the volume of distillate is



made the same as that of the original beer, the tables give directly the percentage of alcohol in the sample.

### 3. *Dry extract*

The Sp. Gr. of the distillation residue (diluted to its original volume) from the determination of the original gravity is required, the excess of this over 1000 is divided by 4.0, which gives the solids in 100 cc. of the beer. The dry extract may also be obtained by evaporation in a platinum dish and weighing.

### 4. *Composition of extract.*

The free maltose or low type malto-dextrins, maltose in malto-dextrin, dextrin in malto-dextrin, and stable dextrin, are determined as under "Malt extracts."

If the malto-dextrin ratio and percentage only is required the method may be shortened, as indicated under "Wort Analysis."

Moritz and Morris state that the "malto-dextrin type" (see "Malt wort") should fall between  $\begin{Bmatrix} 3 M \\ 1 D \end{Bmatrix}$  and  $\begin{Bmatrix} 1 M \\ 3 D \end{Bmatrix}$ . The type gradually becomes lower on storage, *e.g.*, a new strong ale had  $\begin{Bmatrix} 1.7 M \\ 1 D \end{Bmatrix}$  but after storage  $\begin{Bmatrix} 2.4 M \\ 1 D \end{Bmatrix}$ ; ultimately it becomes so low that it disappears entirely by fermentation.

### 5. *Mineral matter.*

(a) Total ash is determined in the usual manner.

(b) Total chlorine. This may be determined by either of two methods:—

(1) A measured quantity of the beer is evaporated to dryness with sodium carbonate and ashed very carefully in a muffle furnace. The chlorine is determined gravimetrically.

(2) The sample is evaporated to dryness with a small amount of  $\text{BaCO}_3$  and ignited to a black ash. The chloride is extracted with hot water and determined volumetrically.

(c) Alkalis. The sample is evaporated to dryness, moistened with sulphuric acid, and ashed. Potassium is determined by the chloroplatinate method and sodium by difference.

(d) Sulphates. The sample is evaporated to dryness with  $\text{NaOH}$ , ashed, and sulphates determined gravimetrically.

### 6. *Preservatives.*

(a) Salicylic acid. 100 cc. of beer is rendered alkaline and the alcohol evaporated off; when cool, the liquid is neutralised with  $\text{HCl}$ , 20 cc. of saturated basic lead acetate solution, and then 20 cc. of  $\text{N.NaOH}$  solution added, and the volume made

up to 200 cc. The liquid is filtered, and 100 cc. of the filtrate is acidified with HCl, filtered, and the filtrate extracted three times with ether. After distilling off the ether, the residue is dissolved in dilute alcohol, made up to 100 cc., and the salicylic acid estimated colorimetrically by means of a fresh, weak solution of ferric chloride. The standard salicylic acid solution is 0.01% strength.

(b) Sulphites.

(i) The beer is distilled with  $H_3PO_4$  into N/100 iodine solution and excess iodine determined as usual with thiosulphate  
 1 cc. N/100 iodine = 0.00032 gram  $SO_2$ .

(ii) J. L. Baker and F. E. Day (*Journ. Inst. Brew.*, 1911, 17, 467) describe another process, of which the following is an outline:—

Marble chips and water are placed in a flask fitted with a dropping funnel and a tube leading to a condenser, the other end of which is connected with two absorption flasks containing N/10 iodine. A little hydrochloric acid is added through the dropping funnel, and the contents of the flask brought to a gentle boil to drive out all air from the apparatus. The beer is then added gradually from the dropping funnel (to avoid frothing), and boiling is continued for  $\frac{1}{2}$  hr., during which time freshly-boiled hydrochloric acid (1:3) is allowed to drop in the flask. Excess iodine is titrated with thio-sulphate.

7. Saccharin.

The following method is according to Allen (*Analyst*, 1888, 13, 105):—

After concentrating to 1/3rd bulk, the beer, if necessary, is made acid with pure phosphoric acid. The liquid is extracted with ether, and the extract, after evaporation of the ether, mixed with  $Na_2CO_3$  and  $NaNO_3$  and ignited. The sulphur of the saccharin molecule yields sodium sulphate, and this is estimated gravimetrically.

$$BaSO_4 \times 0.785 = \text{saccharin.}$$

### Measures used in Brewing.

---

|             |   |             |   |            |     |            |
|-------------|---|-------------|---|------------|-----|------------|
| 1 Butt      | = | 108 gallons | = | 432 Quarts | =   | 864 Pints. |
| 1 Puncheon  | = | 72          | " | =          | 288 | " = 576 "  |
| 1 Hogshead  | = | 54          | " | =          | 216 | " = 432 "  |
| 1 Barrel    | = | 36          | " | =          | 144 | " = 288 "  |
| 1 Kilderkin | = | 18          | " | =          | 72  | " = 144 "  |
| 1 Firkin    | = | 9           | " | =          | 36  | " = 72 "   |

---

Brewers' lbs. per barrel

= excess Sp. Gr. over 1000  $\times$  0.36

# Strength of Wort corresponding to Spirit Indication for the Evaporation Process (Graham, Hoffmann and Redwood).

| Spirit ind. | .0   | .1   | .2   | .3   | .4   | .5   | .6   | .7   | .8   | .9   |
|-------------|------|------|------|------|------|------|------|------|------|------|
| 0           | —    | 0.3  | 0.7  | 1.0  | 1.4  | 1.7  | 2.1  | 2.4  | 2.8  | 3.1  |
| 1           | 3.5  | 3.8  | 4.2  | 4.6  | 5.0  | 5.4  | 5.8  | 6.2  | 6.6  | 7.0  |
| 2           | 7.4  | 7.8  | 8.2  | 8.7  | 9.1  | 9.5  | 9.9  | 10.3 | 10.7 | 11.1 |
| 3           | 11.5 | 11.9 | 12.4 | 12.8 | 13.2 | 13.6 | 14.0 | 14.4 | 14.8 | 15.3 |
| 4           | 15.8 | 16.2 | 16.6 | 17.0 | 17.4 | 17.9 | 18.4 | 18.8 | 19.3 | 19.8 |
| 5           | 20.3 | 20.7 | 21.2 | 21.6 | 22.1 | 22.5 | 22.8 | 23.4 | 23.9 | 24.3 |
| 6           | 24.8 | 25.2 | 25.6 | 26.1 | 26.6 | 27.0 | 27.5 | 28.0 | 28.5 | 29.0 |
| 7           | 29.5 | 30.0 | 30.4 | 30.9 | 31.3 | 31.8 | 32.3 | 32.8 | 33.3 | 33.8 |
| 8           | 34.3 | 34.9 | 35.5 | 36.0 | 36.6 | 37.1 | 37.7 | 38.3 | 38.8 | 39.4 |
| 9           | 40.0 | 40.5 | 41.0 | 41.5 | 42.0 | 42.5 | 43.0 | 43.5 | 44.0 | 44.4 |
| 10          | 44.9 | 45.4 | 46.0 | 46.5 | 47.1 | 47.6 | 48.2 | 48.7 | 49.3 | 49.8 |
| 11          | 50.3 | 50.9 | 51.4 | 51.9 | 52.5 | 53.0 | 53.5 | 54.0 | 54.5 | 55.0 |
| 12          | 55.6 | 56.2 | 56.7 | 57.3 | 57.8 | 58.3 | 58.9 | 59.4 | 59.9 | 60.5 |
| 13          | 61.0 | 61.6 | 62.1 | 62.7 | 63.2 | 63.8 | 64.3 | 64.9 | 65.4 | 66.0 |
| 14          | 66.5 | 67.0 | 67.6 | 68.1 | 68.7 | 69.2 | 69.8 | 70.4 | 70.9 | 71.4 |
| 15          | 72.0 |      |      |      |      |      |      |      |      |      |

## Alcohol Content of Beer and Spirits (Baumhauer-Holzner).

75 cc. of beer are distilled until almost 2/3rd of the liquid has passed over. The distillate is made up to 50 cc. and the Sp. Gr. determined. The table gives the percentage of alcohol by weight.

| Sp. Gr. | 9    | 8    | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|---------|------|------|------|------|------|------|------|------|------|------|
| 0.997   | 1.12 | 1.17 | 1.22 | 1.28 | 1.33 | 1.38 | 1.44 | 1.49 | 1.54 | 1.60 |
| 6       | 1.65 | 1.71 | 1.77 | 1.82 | 1.88 | 1.94 | 2.00 | 2.05 | 2.11 | 2.17 |
| 5       | 2.22 | 2.28 | 2.34 | 2.40 | 2.45 | 2.51 | 2.57 | 2.62 | 2.68 | 2.74 |
| 4       | 2.80 | 2.85 | 2.91 | 2.97 | 3.03 | 3.08 | 3.14 | 3.20 | 3.26 | 3.31 |
| 3       | 3.37 | 3.43 | 3.49 | 3.54 | 3.60 | 3.66 | 3.72 | 3.77 | 3.83 | 3.89 |
| 2       | 3.95 | 4.00 | 4.07 | 4.13 | 4.19 | 4.25 | 4.31 | 4.37 | 4.44 | 4.50 |
| 1       | 4.56 | 4.62 | 4.69 | 4.75 | 4.81 | 4.87 | 4.93 | 5.00 | 5.06 | 5.12 |
| 0       | 5.18 | 5.25 | 5.31 | 5.37 | 5.43 | 5.49 | 5.56 | 5.62 | 5.69 | 5.75 |
| 0.989   | 5.82 | 5.89 | 5.96 | 6.02 | 6.09 | 6.16 | 6.23 | 6.29 | 6.36 | 6.43 |
| 8       | 6.50 | 6.57 | 6.63 | 6.70 | 6.77 | 6.84 | 6.90 | 6.97 | 7.04 | 7.11 |
| 7       | 7.17 | 7.24 | 7.31 | 7.38 | 7.45 | 7.52 | 7.58 | 7.65 | 7.72 | 7.79 |

## SPIRITS.

F. ROBINSON, M.Sc. Tech., B.Sc., F.I.C.

### *Determinations.*

- (1) Alcohol.
- (2) Acidity—(a) fixed, (b) volatile.
- (3) Esters.
- (4) Furfural.
- (5) Aldehyde other than furfural.
- (6) Higher alcohols.
- (7) Total solids.

### *Distillation.*

A quantity of the sample, sufficient to give approximately 50% alcohol by volume when diluted to 200 cc., is distilled until about 20 cc. remain; distillation is then continued in steam until the distillate measures 200 cc. and the residue between 10 and 20 cc. The residue is made up to a known volume.

#### (1) *Alcohol.*

This is determined in the usual manner from the Sp. Gr. of the distillate.

#### (2) *Acidity.*

(a) Fixed acid is determined by titration of an aliquot portion of the residue (above), using phenolphthalein as indicator, and is calculated to tartaric acid.

(b) Volatile acid is determined by titration of an aliquot portion of the distillate (above), using phenolphthalein as indicator, and is calculated to acetic acid. The neutralised sample is preserved for the determination of esters.

#### (3) *Esters.*

To the neutralised distillate from the determination of volatile acid is added 20 cc. of N/10 sodium hydroxide, and hydrolysis is effected by boiling for 1 hr. under a reflux condenser. The excess NaOH is titrated with N/10 sulphuric acid, using phenolphthalein as indicator. The esters are expressed as ethyl acetate.

#### (4) *Furfural.*

##### Reagents.

(i) Alcohol free from aldehyde. The alcohol is purified by digesting with potassium hydroxide and fractionating, collecting the distillate between 78° and 80°C. If any coloration is

given by the distillate with aniline acetate the treatment is repeated.

(ii) Aniline acetate. Equal volumes of aniline, pure acetic acid and water are boiled together for a few minutes.

(iii) Standard furfural solution. 1 gm. of furfural is dissolved in 100 cc. of 50% alcohol, purified as above. A convenient strength for the control solution is 0.05 gm. per 1000 cc. 50% alcohol, prepared by diluting the first solution.

Determination. In a colourless spirit the determination may be carried out directly. Into two Nessler glasses are brought 20 cc. of the spirit and control solution respectively, and to each is added 1 cc. of aniline acetate solution and the colours compared after 10—15 mins. Solution is withdrawn from the darker of two until the two tints are equal. For accurate results the two solutions should be of approximately the same alcoholic strength, hence when the spirit differs from 50% it should be diluted with alcohol or water as required. In the case of a coloured spirit, the determination must be carried out on a portion of the distillate as obtained under "Distillation."

#### (5) *Aldehydes.*

##### Reagents.

(i) Schiff's reagent. 0.15 gm. fuchsine is dissolved in 150 cc. water, and to the solution are added 100 cc. sodium bisulphite solution (Sp. gr. 1.36) and 10 cc. concentrated sulphuric acid. Much mineral acid reduces the sensitiveness of the reagent, on which account J. C. Jones recommends a modification of the above (Allen's "Commercial Organic Analysis").

(ii) Standard aldehyde solution. Aldehyde ammonia is ground in a mortar with ether, allowed to settle, and the ether decanted; repeating several times. The residue is dried, first in air, and then in vacuum over sulphuric acid. 1.386 gm. is dissolved in 50 cc. of 95% alcohol purified from aldehyde (see under furfural), and 22.7 cc. of N. alcoholic sulphuric acid added, the whole made up to 100 cc. with alcohol, and a further 0.8 cc. added to correct for the volume of the ammonium sulphate precipitate. After standing overnight the liquid is filtered. The solution obtained contains 1 gm. of aldehyde in 100 cc. and keeps well. For use 2 cc. are diluted to 100 cc. with 50% alcohol; 1 cc. of the diluted solution = 0.0002 gm. aldehyde; it does not keep.

Determination. To 20 cc. of the distillate obtained as described under "Distillation," and to 20 cc. of the aldehyde standard are added 5 cc. of Schiff's reagent; after standing

20—30 mins. the tints are compared and matched by withdrawing portions of the darker one. Furfural gives only a very slight coloration with the reagent, and this may be neglected.

(6) *Determination of higher alcohols.*

(1) The Allen-Marquardt method, used in Great Britain. 200 cc. of the sample is boiled for 1 hr. under a reflux condenser with 1 cc. of strong potassium hydroxide solution; the liquid is then distilled until about 20 cc. remain in the flask, and steam is passed through until 300 cc. of distillate are collected and the residue in the flask measures about 10 cc. The distillate is divided into two portions for duplicate determinations. The liquid is brought to a Sp. gr. of at least 1.1 by adding saturated salt solution, and extracted four times with carbon tetrachloride, using 40, 30, 20, and 10 cc. respectively. A small amount of ethyl alcohol is removed by carbon tetrachloride together with the higher alcohols; this is removed by shaking with 50 cc. of saturated salt solution and then with 50 cc. of saturated sodium sulphate solution to remove chlorides. The carbon tetrachloride solution is treated with 5 gm. potassium bichromate, 2 gm. concentrated sulphuric acid, and 10 cc. of water, and the whole kept boiling for at least 8 hrs. under a reflux condenser on a water-bath. After oxidation the mixture is diluted with 30 cc. of water and submitted to distillation over a naked flame until about 20 cc. remain in the flask; steam is passed through until 5—10 cc. remain in the flask and the distillate measures 300 cc. The distillate is titrated with N/10 barium hydroxide until neutral to methyl orange, phenolphthalein is added and the titration continued. The acidity shown to methyl orange should not be more than 2 cc. or 10% of the total acidity. Each cc. of N/10 barium hydroxide required in the second stage = 0.0088 gm. of amyl alcohol.

Notes. The mean equivalent of the acids is determined by evaporating the barium salt solution after titration, drying at 130°C., and weighing. The carbon tetrachloride used must previously be boiled with chromic acid mixture for several hours and then distilled over barium carbonate. The corks used in the distillation must be covered with tin foil, if ground glass stoppers are not available; rubber stoppers must not be used.

(ii) The Rose-Herzfeld method; official method in Germany. Details of this method will be found in Allen's "Commercial Organic Analysis," vol. i, or Lunge, "Technical Methods of Chemical Analysis."



(iii) The method of Gerard and Cuniasse, as used in France. In order to remove aldehydes and furfural, 50 cc. of the 50% distillate from the original spirit is treated with 1 gm. of either metaphenylene-diamine hydrochloride, or aniline phosphate, prepared by mixing equal volumes of aniline and phosphoric acid (Sp. gr. 1.453); it is boiled gently for 1 hr. under a reflux condenser, and then distilled as rapidly and completely as possible without charring. The distillate is made up to 50 cc., 10 cc. is measured into a small flask and 10 cc. of pure conc. sulphuric acid is run carefully down the side of the flask. The flask is agitated vigorously and brought to the boil in 15 secs., then allowed to cool. The colour produced is compared with standards containing known amounts of isobutyl alcohol, and prepared in the same manner. The sensitiveness may be increased by adding about 10% of 0.1% furfural solution to standard and sample.

(iv) The Beckman nitrite method is seldom used. Details may be found in Lunge, "Technical Methods of Chemical Analysis."

(7) *Total Solids.*

A convenient quantity is evaporated to dryness on a water-bath. Freshly-distilled spirits leave no residue, but after storage in cask more or less non-volatile matter is taken up. The quantity rarely exceeds 100 grains per gallon.

### Secondary Constituents of Brandy.

(*Lancet* Commission on Brandy; November, 1904.)

| Parts per 100,000 of absolute alcohol. |    |      |    |    |    |    |             |           |           |
|--|----|------|----|----|----|----|-------------|-----------|-----------|
|  |    |      |    |    |    |    | Three Star. | Two Star. | One Star. |
| Acidity                                | .. | ..   | .. | .. | .. | .. | 77.3        | 65.7      | 65.0      |
| Aldehydes                              | .. | ..   | .. | .. | .. | .. | 12.6        | 12.2      | 10.0      |
| Furfural                               | .. | ..   | .. | .. | .. | .. | 1.7         | 2.6       | 2.4       |
| Esters                                 | .. | .... | .. | .. | .. | .. | 110.0       | 103.4     | 97.1      |
| Higher alcohols                        | .. | ..   | .. | .. | .. | .. | 120.6       | 108.5     | 80.3      |
|  |    |      |    |    |    |    | 322.2       | 292.4     | 254.8     |

The sum of the secondary constituents (known as the coefficient of impurity) is rarely lower than 300, and the esters rarely lower than 80 in genuine brandy.



## Secondary Constituents of Whisky.

Schidrowitz and Kaye (*Journ. Soc. Chem. Ind.*, 1905, **24**, 585).

Grams per 100 litres of alcohol.

|                   | Total<br>acid. | Non-<br>Volatile<br>acid. | Esters. | Higher Alcohols.                   |                                     | Aldehydes. | Furfural. |
|-------------------|----------------|---------------------------|---------|------------------------------------|-------------------------------------|------------|-----------|
|                   |                |                           |         | (1) Colori-<br>metric<br>standard. | (2) Allen-<br>Marquardt<br>process. |            |           |
| Highland malts .. | 10-31          | 0-35                      | 33-185  | 328-864                            | 112-235                             | 4-66       | 1.6-6.3   |
| Lowland malts ..  | 6-60           | 0-16                      | 27-87   | 189-897                            | 82-228                              | 8-54       | 0-5.2     |
| Campbeltowns ..   | 12-100         | 0-28                      | 53-140  | 357-930                            | 160-259                             | 11-85      | 2.4-8.0   |
| Islays ..         | 15-36          | 0-33                      | 40-86   | 620-740                            | 155-200                             | 17-40      | 3.8-5.2   |
| Grains ..         | 3-69           | 0-26                      | 20-55   | 39-400                             | 33-80                               | trace-17   | 0-0.9     |

# Analyses of Genuine Jamaica Rums.

W. C. Williams, *Journ. Soc. Chem. Ind.*, 1907, 26, 498.

|                               |         | Grams per 100 litres of alcohol.                  |  |                                 |                                |                                   |                                      |                        |
|-------------------------------|---------|---|--|---------------------------------|--------------------------------|-----------------------------------|--------------------------------------|------------------------|
|                               |         | Total<br>Alcoholic<br>strength<br>% by<br>volume. | Total<br>solids<br>grams<br>per<br>100 cc. | Total<br>acids<br>as<br>acetic. | Vol.<br>acids<br>as<br>acetic. | Esters<br>as<br>ethyl<br>acetate. | Higher<br>alcohols<br>as<br>amyllic. | Furfural.<br>Aldehydes |
| Jamaica rums                  |         |   |  |                                 |                                |                                   |                                      |                        |
|                               |         |   |  |                                 |                                |                                   |                                      |                        |
|                               |         |   |  |                                 |                                |                                   |                                      |                        |
|                               |         |   |  |                                 |                                |                                   |                                      |                        |
| "Common"<br>Clean "           | average | .. 79.1   | 0.43                                       | 78.5                            | 61.0                           | 366.5                             | 98.5                                 | 4.5                    |
|                               | maximum | .. 82.1   | 1.16                                       | 155.0                           | 146.0                          | 1058.0                            | 150.0                                | 11.5                   |
|                               | minimum | .. 68.6   | 0.01                                       | 30.0                            | 21.0                           | 88.0                              | 46.0                                 | 1.0                    |
| "Flavoured"<br>or German rums | average | .. 77.3   | 0.31                                       | 102.5                           | 95.5                           | 768.0                             | 107.0                                | 5.2                    |
|                               | maximum | .. 80.6   | 0.61                                       | 145.0                           | 137.0                          | 1204.0                            | 144.0                                | 12.0                   |
|                               | minimum | .. 66.1   | nil  | 45.0                            | 39.0                           | 391.0                             | 80.0                                 | 2.7                    |
| 7 samples                     |         |   |  |                                 |                                |                                   |                                      | 13.0                   |

# Specific Gravity of Aqueous Solutions of Alcohol.

(Compiled from Sir T. E. Thorpe's "Alcoholimetric Tables.")

"Proof spirit" is defined as that which at the temperature of 51°F. weighs exactly 12/13 of an equal measure of distilled water, also at 51°F.

S=Sp. Gr. 60°F./60°F.

*g*=Weight of alcohol in 100 parts by weight of the mixture at 60°F.

V=Volume of alcohol in 100 volumes of the mixture at 60°F.

P=Percentage of British Fiscal Proof Spirit.

| S       | <i>g</i> | V      | P      |
|---------|----------|--------|--------|
| 0.79359 | 100.00   | 100.00 | 175.35 |
| 0.7940  | 99.87    | 99.92  | 175.21 |
| 0.7950  | 99.55    | 99.72  | 174.87 |
| 0.7960  | 99.22    | 99.52  | 174.52 |
| 0.7970  | 98.90    | 99.32  | 174.16 |
| 0.7980  | 98.57    | 99.12  | 173.80 |
| 0.7990  | 98.24    | 98.91  | 173.44 |
| 0.8000  | 97.91    | 98.70  | 173.07 |
| 0.8010  | 97.59    | 98.49  | 172.71 |
| 0.8020  | 97.25    | 98.28  | 172.33 |
| 0.8030  | 96.91    | 98.06  | 171.95 |
| 0.8040  | 96.57    | 97.84  | 171.56 |
| 0.8050  | 96.23    | 97.62  | 171.17 |
| 0.8060  | 95.89    | 97.39  | 170.77 |
| 0.8070  | 95.55    | 97.16  | 170.37 |
| 0.8080  | 95.20    | 96.93  | 169.96 |
| 0.8090  | 94.85    | 96.69  | 169.55 |
| 0.8100  | 94.50    | 96.45  | 169.13 |
| 0.8110  | 94.15    | 96.21  | 168.71 |
| 0.8120  | 93.80    | 95.97  | 168.28 |
| 0.8130  | 93.44    | 95.72  | 167.86 |
| 0.8140  | 93.08    | 95.47  | 167.41 |
| 0.8150  | 92.72    | 95.22  | 166.96 |
| 0.8160  | 92.36    | 94.97  | 166.51 |
| 0.8170  | 92.00    | 94.71  | 166.06 |
| 0.8180  | 91.63    | 94.45  | 165.60 |
| 0.8190  | 91.27    | 94.19  | 165.14 |
| 0.8200  | 90.90    | 93.92  | 164.67 |
| 0.8210  | 90.53    | 93.65  | 164.20 |
| 0.8220  | 90.16    | 93.38  | 163.72 |
| 0.8230  | 89.79    | 93.11  | 163.24 |
| 0.8240  | 89.41    | 92.83  | 162.75 |
| 0.8250  | 89.03    | 92.55  | 162.26 |
| 0.8260  | 88.65    | 92.26  | 161.76 |
| 0.8270  | 88.27    | 91.98  | 161.26 |
| 0.8280  | 87.88    | 91.69  | 160.75 |
| 0.8290  | 87.50    | 91.40  | 160.24 |
| 0.8300  | 87.11    | 91.11  | 159.73 |
| 0.8310  | 86.73    | 90.82  | 159.21 |
| 0.8320  | 86.34    | 90.52  | 158.69 |
| 0.8330  | 85.95    | 90.22  | 158.16 |

| S      | g     | V     | P      |
|--------|-------|-------|--------|
| 0.8340 | 85.56 | 89.91 | 157.63 |
| 0.8350 | 85.17 | 89.61 | 157.10 |
| 0.8360 | 84.78 | 89.30 | 156.56 |
| 0.8370 | 84.39 | 88.99 | 156.02 |
| 0.8380 | 83.99 | 88.68 | 155.47 |
| 0.8390 | 83.60 | 88.37 | 154.92 |
| 0.8400 | 83.20 | 88.06 | 154.37 |
| 0.8410 | 82.80 | 87.74 | 153.81 |
| 0.8420 | 82.40 | 87.42 | 153.25 |
| 0.8430 | 82.00 | 87.09 | 152.68 |
| 0.8440 | 81.60 | 86.77 | 152.12 |
| 0.8450 | 81.20 | 86.44 | 151.55 |
| 0.8460 | 80.79 | 86.12 | 150.97 |
| 0.8470 | 80.39 | 85.80 | 150.39 |
| 0.8480 | 79.98 | 85.46 | 149.80 |
| 0.8490 | 79.58 | 85.12 | 149.21 |
| 0.8500 | 79.17 | 84.78 | 148.62 |
| 0.8510 | 78.76 | 84.44 | 148.03 |
| 0.8520 | 78.35 | 84.11 | 147.43 |
| 0.8530 | 77.94 | 83.77 | 146.83 |
| 0.8540 | 77.53 | 83.42 | 146.23 |
| 0.8550 | 77.12 | 83.08 | 145.62 |
| 0.8560 | 76.71 | 82.73 | 145.01 |
| 0.8570 | 76.30 | 82.38 | 144.40 |
| 0.8580 | 75.88 | 82.03 | 143.78 |
| 0.8590 | 75.47 | 81.68 | 143.16 |
| 0.8600 | 75.05 | 81.32 | 142.54 |
| 0.8610 | 74.64 | 80.97 | 141.91 |
| 0.8620 | 74.22 | 80.61 | 141.28 |
| 0.8630 | 73.81 | 80.25 | 140.65 |
| 0.8640 | 73.39 | 79.89 | 140.02 |
| 0.8650 | 72.97 | 79.53 | 139.38 |
| 0.8660 | 72.55 | 79.16 | 138.74 |
| 0.8670 | 72.14 | 78.80 | 138.10 |
| 0.8680 | 71.72 | 78.43 | 137.46 |
| 0.8690 | 71.30 | 78.06 | 136.81 |
| 0.8700 | 70.88 | 77.69 | 136.16 |
| 0.8710 | 70.46 | 77.32 | 135.50 |
| 0.8720 | 70.04 | 76.94 | 134.84 |
| 0.8730 | 69.62 | 76.57 | 134.19 |
| 0.8740 | 69.19 | 76.19 | 133.53 |
| 0.8750 | 68.77 | 75.82 | 132.86 |
| 0.8760 | 68.35 | 75.44 | 132.19 |
| 0.8770 | 67.93 | 75.06 | 131.53 |
| 0.8780 | 67.51 | 74.68 | 130.86 |
| 0.8790 | 67.09 | 74.30 | 130.18 |
| 0.8800 | 66.66 | 73.91 | 129.50 |
| 0.8810 | 66.24 | 73.52 | 128.82 |
| 0.8820 | 65.81 | 73.13 | 128.14 |
| 0.8830 | 65.39 | 72.74 | 127.46 |
| 0.8840 | 64.96 | 72.34 | 126.77 |
| 0.8850 | 64.53 | 71.95 | 126.07 |
| 0.8860 | 64.10 | 71.55 | 125.37 |
| 0.8870 | 63.67 | 71.15 | 124.67 |
| 0.8880 | 63.24 | 70.75 | 123.97 |
| 0.8890 | 62.81 | 70.35 | 123.27 |
| 0.8900 | 62.38 | 69.95 | 122.56 |

| S                            | g     | V     | P      |
|------------------------------|-------|-------|--------|
| 0.8910                       | 61.95 | 69.55 | 121.85 |
| 0.8920                       | 61.52 | 69.14 | 121.14 |
| 0.8930                       | 61.09 | 68.74 | 120.42 |
| 0.8940                       | 60.66 | 68.33 | 119.70 |
| 0.8950                       | 60.23 | 67.92 | 118.98 |
| 0.8960                       | 59.80 | 67.50 | 118.26 |
| 0.8970                       | 59.37 | 67.08 | 117.54 |
| 0.8980                       | 58.93 | 66.67 | 116.81 |
| 0.8990                       | 58.50 | 66.25 | 116.07 |
| 0.9000                       | 58.06 | 65.83 | 115.33 |
| 0.9010                       | 57.62 | 65.41 | 114.59 |
| 0.9020                       | 57.18 | 64.98 | 113.84 |
| 0.9030                       | 56.75 | 64.56 | 113.10 |
| 0.9040                       | 56.31 | 64.13 | 112.35 |
| 0.9050                       | 55.87 | 63.70 | 111.59 |
| 0.9060                       | 55.42 | 63.26 | 110.82 |
| 0.9070                       | 54.98 | 62.83 | 110.06 |
| 0.9080                       | 54.54 | 62.39 | 109.29 |
| 0.9090                       | 54.10 | 61.95 | 108.52 |
| 0.9100                       | 53.65 | 61.51 | 107.74 |
| 0.9110                       | 53.21 | 61.07 | 106.97 |
| 0.9120                       | 52.77 | 60.63 | 106.20 |
| 0.9130                       | 52.33 | 60.19 | 105.42 |
| 0.9140                       | 51.88 | 59.74 | 104.63 |
| 0.9150                       | 51.43 | 59.29 | 103.84 |
| 0.9160                       | 50.98 | 58.83 | 103.05 |
| 0.9170                       | 50.53 | 58.38 | 102.24 |
| 0.9180                       | 50.08 | 57.92 | 101.43 |
| 0.9190                       | 49.63 | 57.46 | 100.62 |
| British Fiscal Proof Spirit. |       |       |        |
| 0.91976                      | 49.28 | 57.10 | 100.00 |
| 0.9200                       | 49.17 | 56.99 | 99.80  |
| 0.9210                       | 48.71 | 56.52 | 98.98  |
| 0.9220                       | 48.25 | 56.05 | 98.16  |
| 0.9230                       | 47.79 | 55.58 | 97.33  |
| 0.9240                       | 47.33 | 55.10 | 96.49  |
| 0.9250                       | 46.87 | 54.62 | 95.65  |
| 0.9260                       | 46.40 | 54.14 | 94.80  |
| 0.9270                       | 45.94 | 53.65 | 93.95  |
| 0.9280                       | 45.47 | 53.16 | 93.09  |
| 0.9290                       | 45.00 | 52.67 | 92.23  |
| 0.9300                       | 44.53 | 52.18 | 91.36  |
| 0.9310                       | 44.06 | 51.68 | 90.49  |
| 0.9320                       | 43.59 | 51.18 | 89.61  |
| 0.9330                       | 43.11 | 50.67 | 88.71  |
| 0.9340                       | 42.62 | 50.15 | 87.81  |
| 0.9350                       | 42.13 | 49.63 | 86.89  |
| 0.9360                       | 41.64 | 49.10 | 85.97  |
| 0.9370                       | 41.15 | 48.57 | 85.04  |
| 0.9380                       | 40.65 | 48.04 | 84.10  |
| 0.9390                       | 40.15 | 47.50 | 83.15  |
| 0.9400                       | 39.65 | 46.95 | 82.19  |
| 0.9410                       | 39.15 | 46.40 | 81.23  |
| 0.9420                       | 38.64 | 45.85 | 80.26  |
| 0.9430                       | 38.12 | 45.28 | 79.26  |
| 0.9440                       | 37.60 | 44.71 | 78.26  |

| S      | g     | V     | P     |
|--------|-------|-------|-------|
| 0.9450 | 37.07 | 44.13 | 77.24 |
| 0.9460 | 36.54 | 43.54 | 76.21 |
| 0.9470 | 36.00 | 42.95 | 75.17 |
| 0.9480 | 35.46 | 42.35 | 74.12 |
| 0.9490 | 34.92 | 41.74 | 73.05 |
| 0.9500 | 34.37 | 41.13 | 71.98 |
| 0.9510 | 33.81 | 40.50 | 70.87 |
| 0.9520 | 33.25 | 39.87 | 69.76 |
| 0.9530 | 32.67 | 39.22 | 68.62 |
| 0.9540 | 32.09 | 38.57 | 67.48 |
| 0.9550 | 31.50 | 37.89 | 66.29 |
| 0.9560 | 30.90 | 37.20 | 65.09 |
| 0.9570 | 30.28 | 36.50 | 63.85 |
| 0.9580 | 29.66 | 35.79 | 62.60 |
| 0.9590 | 29.03 | 35.06 | 61.32 |
| 0.9600 | 28.39 | 34.33 | 60.03 |
| 0.9610 | 27.73 | 33.56 | 58.68 |
| 0.9620 | 27.06 | 32.79 | 57.33 |
| 0.9630 | 26.37 | 31.99 | 55.93 |
| 0.9640 | 25.68 | 31.18 | 54.51 |
| 0.9650 | 24.97 | 30.34 | 53.04 |
| 0.9660 | 24.23 | 29.48 | 51.53 |
| 0.9670 | 23.48 | 28.69 | 49.98 |
| 0.9680 | 22.71 | 27.69 | 48.38 |
| 0.9690 | 21.93 | 26.77 | 46.77 |
| 0.9700 | 21.14 | 25.83 | 45.14 |
| 0.9710 | 20.34 | 24.85 | 43.47 |
| 0.9720 | 19.53 | 23.91 | 41.77 |
| 0.9730 | 18.72 | 22.94 | 40.06 |
| 0.9740 | 17.90 | 21.96 | 38.35 |
| 0.9750 | 17.08 | 20.97 | 36.61 |
| 0.9760 | 16.25 | 19.98 | 34.87 |
| 0.9770 | 15.43 | 18.99 | 33.15 |
| 0.9780 | 14.61 | 18.00 | 31.42 |
| 0.9790 | 13.80 | 17.02 | 29.70 |
| 0.9800 | 12.99 | 16.04 | 27.99 |
| 0.9810 | 12.20 | 15.08 | 26.32 |
| 0.9820 | 11.42 | 14.13 | 24.66 |
| 0.9830 | 10.65 | 13.20 | 23.02 |
| 0.9840 | 9.91  | 12.29 | 21.44 |
| 0.9850 | 9.18  | 11.40 | 19.87 |
| 0.9860 | 8.46  | 10.51 | 18.34 |
| 0.9870 | 7.76  | 9.65  | 16.85 |
| 0.9880 | 7.08  | 8.80  | 15.38 |
| 0.9890 | 6.41  | 7.98  | 13.94 |
| 0.9900 | 5.76  | 7.18  | 12.53 |
| 0.9910 | 5.13  | 6.40  | 11.16 |
| 0.9920 | 4.51  | 5.63  | 9.82  |
| 0.9930 | 3.90  | 4.88  | 8.51  |
| 0.9940 | 3.31  | 4.14  | 7.24  |
| 0.9950 | 2.73  | 3.42  | 5.98  |
| 0.9960 | 2.17  | 2.71  | 4.73  |
| 0.9970 | 1.61  | 2.02  | 3.52  |
| 0.9980 | 1.07  | 1.34  | 2.33  |
| 0.9990 | 0.53  | 0.66  | 1.16  |
| 0.9998 | 0.10  | 0.13  | 0.23  |

## Dilution of Alcohol to 30 per cent. by Volume at 15° C. (Brix).

| 100 cc. alcohol<br>% by vol. | water<br>cc. | 100 cc. alcohol<br>% by vol. | water<br>cc. | 100 cc. alcohol<br>% by vol. | water<br>cc. |
|------------------------------|--------------|------------------------------|--------------|------------------------------|--------------|
| 30                           | 0.0          | 49                           | 64.1         | 68                           | 129.4        |
| 31                           | 3.3          | 50                           | 67.5         | 69                           | 132.8        |
| 32                           | 6.6          | 51                           | 70.9         | 70                           | 136.3        |
| 33                           | 10.0         | 52                           | 74.3         | 71                           | 139.7        |
| 34                           | 13.4         | 53                           | 77.7         | 72                           | 143.2        |
| 35                           | 16.7         | 54                           | 81.2         | 73                           | 146.7        |
| 36                           | 20.1         | 55                           | 84.6         | 74                           | 150.2        |
| 37                           | 23.4         | 56                           | 88.0         | 75                           | 153.6        |
| 38                           | 26.8         | 57                           | 91.4         | 76                           | 157.1        |
| 39                           | 30.2         | 58                           | 94.9         | 77                           | 160.6        |
| 40                           | 33.5         | 59                           | 98.3         | 78                           | 164.1        |
| 41                           | 36.9         | 60                           | 101.8        | 79                           | 167.6        |
| 42                           | 40.3         | 61                           | 105.2        | 80                           | 171.1        |
| 43                           | 43.7         | 62                           | 108.6        | 81                           | 174.6        |
| 44                           | 47.1         | 63                           | 112.1        | 82                           | 178.1        |
| 45                           | 50.5         | 64                           | 115.5        | 83                           | 181.6        |
| 46                           | 53.9         | 65                           | 119.9        | 84                           | 185.1        |
| 47                           | 57.3         | 66                           | 122.4        | 85                           | 188.6        |
| 48                           | 60.7         | 67                           | 125.9        |                              |              |

## Boiling-points of Alcohol Solutions.

| Vapour<br>°C. | % Alcohol by volume. |             | Vapour<br>°C. | % Alcohol by volume. |             |
|---------------|----------------------|-------------|---------------|----------------------|-------------|
|               | Liquid.              | Distillate. |               | Liquid.              | Distillate. |
| 77.2          | 92                   | 93          | 87.5          | 20                   | 71          |
| 77.5          | 90                   | 92          | 88.7          | 18                   | 68          |
| 77.8          | 85                   | 91.5        | 90.0          | 15                   | 66          |
| 78.2          | 80                   | 90.5        | 91.2          | 12                   | 61          |
| 78.7          | 75                   | 90          | 92.5          | 10                   | 55          |
| 79.4          | 70                   | 89          | 93.7          | 7                    | 50          |
| 80.0          | 65                   | 87          | 95.0          | 5                    | 42          |
| 81.2          | 50                   | 85          | 96.2          | 3                    | 36          |
| 82.5          | 40                   | 82          | 97.5          | 2                    | 18          |
| 83.7          | 35                   | 80          | 98.7          | 1                    | 13          |
| 85.0          | 30                   | 78          | 100.0         | 0                    | -           |
| 86.2          | 25                   | 76          |               |                      |             |



## Preparation of Brandy containing 24.7 per cent. by weight of Alcohol (30 per cent. by volume).

100 cc. of brandy containing % alcohol (by weight) are mixed with cc. alcohol or water at 15°C.

| 100 cc. alc.<br>alc. % | alc. cc.  | 100 cc. water<br>alc. % | water cc. | 100 cc. water<br>alc. % | water cc. | 100 cc. water<br>alc. % | water cc. | 100 cc. water<br>alc. % | water cc. |
|------------------------|-----------|-------------------------|-----------|-------------------------|-----------|-------------------------|-----------|-------------------------|-----------|
| 22.5                   | 3.52      | 35                      | 39.7      | 52                      | 101.2     | 69                      | 157.2     | 86                      | 207.1     |
| 23                     | 2.71      | 36                      | 43.5      | 53                      | 104.7     | 70                      | 160.3     | 87                      | 209.9     |
| 23.5                   | 1.90      | 37                      | 47.2      | 54                      | 108.1     | 71                      | 163.4     | 88                      | 212.6     |
| 24                     | 1.09      | 38                      | 51.0      | 55                      | 111.5     | 72                      | 166.4     | 89                      | 215.2     |
| 24.5                   | 0.29      | 39                      | 54.7      | 56                      | 114.9     | 73                      | 169.5     | 90                      | 217.9     |
|                        |           | 40                      | 58.4      | 57                      | 118.3     | 74                      | 172.5     | 91                      | 220.5     |
|                        | cc. water | 41                      | 62.0      | 58                      | 121.6     | 75                      | 175.5     | 92                      | 223.1     |
| 25                     | 1.3       | 42                      | 65.7      | 59                      | 124.9     | 76                      | 178.5     | 93                      | 225.6     |
| 26                     | 5.2       | 43                      | 69.3      | 60                      | 128.3     | 77                      | 181.5     | 94                      | 228.1     |
| 27                     | 9.1       | 44                      | 72.9      | 61                      | 131.5     | 78                      | 184.4     | 95                      | 230.6     |
| 28                     | 12.9      | 45                      | 76.5      | 62                      | 134.8     | 79                      | 187.3     | 96                      | 233.1     |
| 29                     | 16.8      | 46                      | 80.1      | 63                      | 138.1     | 80                      | 190.2     | 97                      | 235.5     |
| 30                     | 20.7      | 47                      | 83.7      | 64                      | 141.3     | 81                      | 193.1     | 98                      | 237.8     |
| 31                     | 24.5      | 48                      | 87.2      | 65                      | 144.5     | 82                      | 196.0     | 99                      | 240.1     |
| 32                     | 28.3      | 49                      | 90.8      | 66                      | 147.7     | 83                      | 198.8     | 100                     | 242.4     |
| 33                     | 32.1      | 50                      | 94.3      | 67                      | 150.9     | 84                      | 201.6     |                         |           |
| 34                     | 35.9      | 51                      | 97.8      | 68                      | 154.0     | 85                      | 204.4     |                         |           |

## Composition of Fusel Oils (Windisch).

|                     | Potato<br>fusel oil. | Potato fusel oil<br>aq. and alc. free. | Rye<br>fusel oil. | Rye fusel oil<br>aq. and alc. free. |
|---------------------|----------------------|--|-------------------|-------------------------------------|
|                     | Grm. per kgm.        |  |                   |                                     |
| Water               | 116.1                | -                                      | 101.5             | -                                   |
| Ethyl alcohol       | 27.6                 | -                                      | 40.2              | -                                   |
| n-Propyl alcohol    | 58.7                 | 68.54                                  | 31.7              | 36.9                                |
| Isobutyl alcohol    | 208.5                | 243.5                                  | 135.3             | 157.6                               |
| Amyl alcohol        | 588.8                | 687.6                                  | 685.3             | 798.5                               |
| Free fatty acids    | 0.09                 | 0.11                                   | 1.37              | 1.60                                |
| Fatty acid esters   | 0.17                 | 0.20                                   | 2.62              | 3.05                                |
| Furfurol            | 0.04                 | 0.05                                   | 0.18              | 0.21                                |
| Hexyl alcohol, etc. | -                    | -                                      | 1.14              | 1.33                                |
| Terpene             | -                    | -                                      | 0.28              | 0.33                                |
| Terpin hydrate      | -                    | -                                      | 0.41              | 0.48                                |

## TANNIN MATERIALS.

W. MATHER, Assoc. M.C.T., A.I.C.

### Qualitative Examination.

In the following tests, the tannin solution should contain 0.4% of tannin. A solution of this strength contains the required percentage of tannin for the quantitative estimation of the tannin, and, according to Procter, the following amounts of the different materials are required to make 1 litre of such a solution.

| BARKS, &c.            | Grm.   | EXTRACTS.              | Grm.  |
|-----------------------|--------|------------------------|-------|
| Algarobilla .. .. .   | 8-9    | Chestnut (liquid) ..   | 14    |
| Canaigre .. .. .      | 15-18  | "    (solid) ..        | 7     |
| Chestnut wood .. ..   | 45     | Cutch .. .. .          | 7     |
| Divi-divi .. .. .     | 9      | Cambier (block) ..     | 10    |
| Hemlock bark .. ..    | 32-36  | "    (cube) ..         | 7     |
| Mangrove bark .. ..   | 10     | Hemlock .. .. .        | 10-14 |
| Myrobalans .. .. .    | 15     | Mangrove (liquid) ..   | 9     |
| Oak bark .. .. .      | 30-36  | "    (solid) ..        | 7     |
| Oak wood .. .. .      | 50-100 | Mimosa .. .. .         | 10-12 |
| Pine bark .. .. .     | 32     | Myrobalans (liquid) .. | 16    |
| Pistacia lentiscus .. | 20-22  | Oak wood (Sp. Gr. 1.2  |       |
| Quebracho wood ..     | 20-22  | or over) .. .. .       | 15    |
| Spent tans .. .. .    | 50-100 | Pine bark .. .. .      | 16    |
| Sumach .. .. .        | 15-16  | Quebracho (solid) ..   | 6     |
| Valonia .. .. .       | 14-15  | "    (liquid) ..       | 9-13  |
| Valonia beard .. ..   | 10-11  |                        |       |
| Willow bark .. .. .   | 36     |                        |       |

### *Preparation of Infusion for examination and estimation of Tannin.*

The ground material is usually treated in a Procter extractor. The extractor is fitted up as follows: The stem of a thistle funnel is bent twice at right angles to form a syphon; the head of the thistle funnel, covered with silk gauze, rests on the bottom of a beaker; the other limb is lengthened by means of glass tubing connected by means of india-rubber tubing to which is fitted a screw clamp to control the rate of syphoning. The beaker is filled with well-washed sand to a point half way up the thistle head, and the necessary amount of tannin material added. 500 cc. of water are placed in the beaker, and the material allowed to soak for several hours at about 30°C. After heating the beaker and contents in a water-bath to a temperature not exceeding 50°C. the liquid is syphoned off in not less than 3 hrs. The greater part of the tannin having been extracted, 500 cc. of boiling water is added in the beaker and the liquid syphoned off. The extract is cooled and made up to 1 litre with water.

### *Gelatin test.*

A solution of 10 grm. gelatin and 100 grm. salt in a litre of water is added drop by drop to 2-3 cc. of the tannin

solution, when the formation of a precipitate or turbidity denotes the presence of some tanning material. This reaction is given by all tannins, but excess of gelatin must be avoided, as the precipitate is soluble in excess.

The tanning materials may be divided into three main classes: catechol tannins, pyrogallol tannins, mixed tannins.

*Bromine water test.*

Bromine water (4-5 grm. bromine per litre) is added gradually to a faintly acid solution of the tannin (acetic acid must be added if necessary), until the solution smells strongly of bromine. The formation of a precipitate, usually flocculent, generally denotes the presence of a catechol tannin. Precipitates formed only after long standing should be neglected.

*Iron test.*

A 1% solution of ferric ammonium sulphate is added to the tannin solution. Catechol tannins give a greenish-black coloration or precipitate; mixed tannins give a bluish- or velvet-black; pyrogallol tannins give a blue-black. These reactions are quite empirical, and classification by means of them is somewhat artificial. The individual members of these groups may often be identified by their reactions with certain other reagents, including copper sulphate and ammonia, nitrous acid, stannous chloride, conc. sulphuric acid, lime water, etc. The identification is only effected by a consideration of the action of the tannin with all these reagents, as the differences between the action of a certain reagent on different tannins are frequently only of degree. Full tables for the identifications are given in Procter's "Leather Industries Laboratory Book."

*Formaldehyde test.* 10 cc. formaldehyde (40%), 5 cc. hydrochloric acid, and 50 cc. of the tannin solution (0.4% tannin) are boiled for half an hour in a flask under a reflux condenser. Note is taken whether the solution remains clear, or whether a precipitate is formed during the boiling. If necessary, the liquid is filtered, 10 cc. of the filtrate taken in a test-tube, 1 cc. iron alum (1%) and 5 grm. sodium acetate added, and it is noted whether a bluish-violet coloration appears. Catechol tannins are completely precipitated with formaldehyde and hydrochloric acid, the filtrate giving no violet coloration with iron. Some pyrogallol tannins (oakwood, chestnut, etc.) remain quite clear during boiling, whereas others are partially precipitated, but all pyrogallol tannins can be detected by the iron test in the filtrate.

*Lead acetate test.* 5 cc. of 10% lead acetate solution are added to 5 cc. of the tannin solution, and a portion of the clear filtrate is mixed with an excess of 10% caustic soda solution. A yellow coloration is produced.

## Identification of Tannins (Stiasny).

**Acetic acid—lead acetate test.** The presence of acetic acid prevents the lead acetate from precipitating catechol tannins, whereas the pyrogallol tannins are more or less completely precipitated. 5 cc. of 0.4 per cent. tannin solution are taken, and 10 cc. acetic acid (10 per cent.) and 5 cc. lead acetate (10 per cent.) added.

|  |  |   |   |
|--|--|---|---|
| <p>50 cc. tannin solution (0.4%) boiled with 25 cc. of mixture containing 1 part conc. HCl and 2 parts formaldehyde (40%) for 30 minutes under reflux condenser.</p> | <p>No precipitation until after 15 minutes boiling.<br/>Inference: Mixed tannins or other materials.*</p>  | <p>Confirmatory tests:<br/>Original tannin solution<br/>+ bromine water: no ppt.<br/>+ ammonium sulphide: ppt.<br/>5 cc. tannin solution (0.4%)<br/>+ acetic acid lead-acetate.<br/>Filtrate with iron alum soln.</p> | <p>Confirmatory tests:<br/>Original tannin solution.<br/>5 cc. tannin solution (0.4%)<br/>+ bromine water.<br/>No precipitation.<br/>Sumach<br/>Divi-divi<br/>Algarobilla<br/>Galls<br/>Bablah<br/>Teri</p> |
| <p>Complete precipitation:<br/>Filtrate + iron alum and sodium acetate: no violet coloration.<br/>Inference: Catechol tannins.</p>                                   | <p>No precipitation after 15 minutes boiling.<br/>Filtrate + iron alum and sodium acetate: violet coloration.<br/>Inference: Pyrogallol tannins.</p> | <p>Confirmatory tests:<br/>Original tannin solution<br/>+ bromine water: no ppt.<br/>+ ammonium sulphide: ppt.<br/>5 cc. tannin solution (0.4%)<br/>+ acetic acid lead-acetate.<br/>Filtrate with iron alum soln.</p> | <p>Confirmatory tests:<br/>Original tannin solution.<br/>5 cc. tannin solution (0.4%)<br/>+ bromine water.<br/>No precipitation.<br/>Sumach<br/>Divi-divi<br/>Algarobilla<br/>Galls<br/>Bablah<br/>Teri</p> |
| <p>50 cc. tannin solution (0.4%) boiled with 25 cc. of mixture containing 1 part conc. HCl and 2 parts formaldehyde (40%) for 30 minutes under reflux condenser.</p> | <p>No precipitation until after 15 minutes boiling.<br/>Inference: Mixed tannins or other materials.*</p>  | <p>Confirmatory tests:<br/>Original tannin solution<br/>+ bromine water: no ppt.<br/>+ ammonium sulphide: ppt.<br/>5 cc. tannin solution (0.4%)<br/>+ acetic acid lead-acetate.<br/>Filtrate with iron alum soln.</p> | <p>Confirmatory tests:<br/>Original tannin solution.<br/>5 cc. tannin solution (0.4%)<br/>+ bromine water.<br/>No precipitation.<br/>Sumach<br/>Divi-divi<br/>Algarobilla<br/>Galls<br/>Bablah<br/>Teri</p> |

\* Certain non-tannin materials, e.g. gallic acid or colouring matters usually present in tannins, give precipitates with formaldehyde.

# Reactions of Tannins (Stiasny).

|                           | Formaldehyde—HCl test   |                    | Br. test. | Ammonium sulphide test.          | Lead acetate test. Filtrate + NaOH. | Acetic acid + lead acetate test. Filtrate: + iron alum. |
|---------------------------|---|--------------------|-----------|----------------------------------|-------------------------------------|---|
|                           | During 15 mins. boiling. Filtrate: + iron alum + sodium acetate |                    |           |                                  |                                     |   |
| Quebracho .....           | ppt.  | no coloration      | ppt.      | no ppt.                          | yellowish                           | no ppt.   |
| Sulphited quebracho ..... | ppt.  | "                  | ppt.      | no ppt.                          | yellowish                           | no ppt. (but PbSO <sub>4</sub> )                        |
| Mangrove .....            | ppt.  | "                  | ppt.      | no ppt.                          | colorless                           | green   |
| Ulm .....                 | ppt.  | "                  | ppt.      | no ppt.                          | yellowish                           | green   |
| Gambier .....             | ppt.  | "                  | ppt.      | no ppt.                          | —                                   | green   |
| Mimosa .....              | ppt.  | "                  | ppt.      | ppt.                             | colorless                           | deep bluish violet                                      |
| Oak bark .....            | ppt.  | violet             | ppt.      | ppt. (after standing over-night) | colorless                           | —   |
| Hemlock .....             | ppt.  | no coloration      | ppt.      |                                  | yellowish                           | green   |
| Pistacia .....            | ppt.  | deep bluish violet | ppt.      | ppt.                             | yellow                              | green to violet   |
| Chestnut .....            | no ppt.   | "                  | no ppt.   | ppt.                             | colorless                           | faint violet  |
| Oakwood .....             | no ppt.   | "                  | no ppt.   | ppt.                             | colorless                           | colorless   |
| Myrobalans .....          | ppt.  | "                  | no ppt.   | ppt.                             | colorless                           | violet  |
| Sumach .....              | ppt.  | "                  | no ppt.   | ppt.                             | yellow                              | violet  |
| Valonia .....             | turbid  | "                  | no ppt.   | ppt.                             | colorless                           | colorless   |
| Divi-divi .....           | turbid  | "                  | no ppt.   | ppt.                             | colorless                           | violet  |
| Algarobilla .....         | turbid  | "                  | no ppt.   | ppt.                             | colorless                           | violet  |
| Wood pulp .....           | no ppt.   | no coloration      | no ppt.   | not characteristic.              | deep yellow                         | colorless   |

### *Detection of Sulphite-Cellulose Liquors in Tanning Extracts.*

**Procter-Hirst test.** 0.5 cc. of aniline is added to 5 cc. of the solution of tanning extract, and after vigorously shaking a turbid emulsion is obtained; 2 cc. of conc. hydrochloric acid are added. If the solution becomes clear sulphite-cellulose liquors are absent; a pronounced precipitate indicates the presence of sulphite-cellulose.

### *Artificial tanning materials.*

Artificial tannins of the Neradol type also give the Procter-Hirst reaction. Wood-pulp (sulphite-cellulose) when in admixture may be detected as follows: One or two drops of a 1% solution of alum and about 5 gm. of solid ammonium acetate are added to 10 cc. of a solution of 5% of the extract, and the mixture shaken vigorously. Wood-pulp gives a precipitate, whereas Neradol tannins remain clear.

## **Estimation of Tannin.**

An aqueous solution containing 0.4% tannin is made up as previously stated.

### *(a) Löwenthal and Schroeder's method.*

**Reagents:** Permanganate solution. 10 gm. of the pure salt are dissolved in 6 litres of distilled water.

**Indigo solution.** 30 gm. sodium sulphindigotate are dissolved in 3 litres of dilute sulphuric acid (1:5); 3 litres of distilled water are added, with stirring, until complete solution is obtained; then filtered.

**Tannin solution.** 2 gm. pure tannic acid are dissolved in litre of water.

**Method:** 10–20 cc. tannin solution, 20 cc. Indigo solution, and 750 cc. distilled water are titrated with the permanganate solution until a golden yellow coloration is produced.

A second portion is taken and the tannin removed by digesting 50 cc. for 24 hours with 3 gm. hide powder, filtering, adding Indigo solution, and titrating with permanganate in the same manner as the above solution.

### *(b) Procter's Modification.*

This is practically the only titration method used in England at the present time. It is used for dilute solutions, and is not particularly affected by the presence of gallic acid. It is therefore well adapted for analyses of weak and waste liquors, spent tans, and for sumach and myrobalans.

The reagents used are:—

1. Pure potassium permanganate, 5 gm. per litre. This is diluted to 10 times its volume as required.

2. A solution of 5 gm. pure indigo carmine and 50 gm. conc. sulphuric acid per litre. This solution must be filtered.



3. Pure tannin solution, 3 grm. of tannic acid per litre.

25 cc. of the indigo carmine solution and 750 cc. water are titrated with the dilute permanganate, which is run in steadily drop by drop, the solution being rapidly stirred in a regular manner. The end point is shown by a faint pinkish rim in the yellow liquid, and is extremely delicate. This titration is repeated at least once, and the average figure taken. The process is then repeated, titrations being made in presence of 5 cc. of the tannin solution. The process is again repeated in presence of the tannin infusion under examination, the volume used being such as will consume approximately the same amount of permanganate as the standard tannin solution. The total astringent matter is then calculated as tannin.

Usually it is necessary to detannise the infusion by means of hide powder, as in the gravimetric method (see later), or by gelatin, and then to determine the amount of astringent matter other than gelatin.

#### OFFICIAL METHOD FROM 1907 OF THE INTERNATIONAL ASSOCIATION OF LEATHER TRADES CHEMISTS.

A quantity of air-dried hide-powder, corresponding to 6.5 grm. actual dry hide-powder, is weighed out, and mixed with about 10 times the weight of water. 10 cc. of a solution of  $\text{Cr}_2\text{Cl}_3(\text{OH})_3$  (prepared by addition of 3.9 grm. of  $\text{Na}_2\text{CO}_3$  to 13 grm.  $\text{Cr}_2\text{Cl}_3 \cdot 12\text{H}_2\text{O}$  in one litre of water) are added, and the mixture churned, that is, agitated in a bottle revolving at not less than 60 R.P.M., for one hour. At the end of this period, the powder is squeezed in linen to free from residual liquor, washed with tap water, and finally with distilled water, so that on addition of one drop of 10 per cent.  $\text{K}_2\text{CrO}_4$  and 4 drops of N/10  $\text{AgNO}_3$  to 50 cc. of the washings, a brick-red colour appears. The powder is squeezed fairly dry and then weighed, the weight being about 20 grm. The powder is introduced into a stoppered bottle of 500 or 1000 cc. capacity, made up to 26.5 grm. with distilled water, and 100 cc. of unfiltered tannin infusion (see below) added. The bottle is well agitated by hand or by machinery for 15 minutes, when the mixture is squeezed through linen, and the liquor filtered through a dry filter until the filtrate is clear. 50 cc. of the filtrate are evaporated to dryness in a nickel dish on the water-bath, the drying being completed in an air-oven at  $100^\circ\text{C}.$ , and the residue is weighed (W.).

Whilst the hide powder is being churned for one hour, the tannin infusion is made by dissolving an amount of the



substance (W) as shown in the table given (extracts in hot water; raw materials in the Procter extractor), cooling to between 15° and 20°C., and making up to 1 litre. 100 cc. of this solution are used for the non-tannin estimation as above, the rest being filtered through an acid-extracted filter, the first 200 cc. of filtrate being rejected, to allow for the absorption of tannin by the filter-paper. 50 cc. of the next amount of filtrate are evaporated in a nickel dish on the water-bath, dried at 100°C. in the air-oven, and weighed ( $W_2$ ).

$$\text{Total soluble matter} = \frac{W_2 \times 20 \times 100}{W} \%$$

$$\text{Soluble non-tannin} = \frac{W_1 \times 6 \times 20 \times 100}{5 \times W} \%$$

Soluble tannin = total soluble - soluble non-tannin.

### HIDE POWDER.

The hide powder (batch B 8) has been tested by the Hide Powder Committee of the Society of Leather Trades Chemists, with the following results:—

Moisture: 9.2%.

Acidity: 3.55c.c. N/10 NaOH per 6.5 grms. powder.

Soluble Matter. 0.782 grms.

Blank Test: 0.050 grms.

Heterogeneity: 13.1.

Relative Specific Surface: 102.

The B 8 hide powder became the official powder of the British Section of the Society of Leather Trades Chemists as from September 1st, 1921.

### OFFICIAL AMERICAN METHOD.

The following tests are carried out:—

#### I. Crude materials.

(a) Moisture. 10 gm. of the sample are dried as under "Evaporation and Drying" (see later) until constant in weight, and loss in weight is counted as moisture.

(b) Preparation for extraction. The material is dried thoroughly at not more than 60°C., and ground through a 20 mesh sieve.

(c) Amount of sample and proportion of water. These must be adjusted so as to give 0.375 to 0.425 tannin per 100 cc. of solution.

(d) Extraction. This must be carried out under such conditions that the aqueous extract is removed from the

influence of continued high temperature. At least 400 cc. must be removed and not further heated, and a thin layer of cotton wool should be used in order to prevent fine matter from passing over. Gelatin-salt solution should be used to determine whether the extraction is complete.

(e) Analysis. This is carried out as for "Extracts."

## II. Extracts.

(f) Preparation of solution. The extract should be weighed off in a stoppered weighing bottle at room temperature, and the amount used should be such as will give 0.375 to 0.425 gm. of tannin per 100 cc. of solution. The extract is dissolved in 900 cc. of water at 85°C., and made up to 1000 cc. after standing not less than 12, and not more than 20, hours. The solution must not be cooled below 20°C.

(g) Total solids. 100 cc. of solution are evaporated, dried, and weighed.

(h) Soluble solids. 1 gm. of well-washed kaolin is mixed with 75 cc. of the solution, and the mixture filtered through a S. and S. No. 590, or Munktell's No. 1 F 15 cm. single, pleated filter paper. The filtrate is returned to the filter paper so as to keep it full for an hour. At the end of an hour, the solution is poured off from the paper, or removed by means of a pipette. About 600 cc. of the original tannin solution is then filtered through the same paper until clear, when the filtrate is collected, and the first 100 cc. evaporated to dryness, and the residue weighed.

(i) Non-tannins. A quantity of air-dried hide powder is mixed with ten times its weight of water and 3% chrome alum in solution. The mixture is thoroughly shaken for several hours and allowed to stand overnight. The hide powder is then washed in linen until the washing gives no precipitate with barium chloride. The wet hide powder is squeezed until it contains 71 to 74% of water, and the moisture is determined on about 20 gm. of the sample. To 200 cc. of the original tannin solution is added a quantity of wet hide powder corresponding to 12½ gm. dry hide. The mixture is shaken for 10 minutes in a mechanical shaker, and then filtered through linen, and squeezed. 2 gm. of well-washed kaolin are added to the filtrate, which is then filtered through a folded filter paper (No. 1 F. Swedish is recommended), the filtrate being returned to the paper until it filters quite clear. 100 cc. of the clear filtrate are evaporated to dryness and the residue weighed.

(j) Tannin. This is the difference between the soluble solids and the non-tannins.

### III. Analysis of Liquors.

(*k*) Liquors must be diluted so as to contain approximately 0.7 grm. of solids per 100 cc. of solution.

(*l*) Total solids. As under "Extracts (*g*)."

(*m*) Soluble solids. As under "Extracts (*h*)."

(*n*) Non-tannins. 200 cc. of the solution, diluted as in (*k*), are shaken with wet chromed hide powder (71—74% moisture), corresponding to dry hide powder, as in the following table:—

| Tannin per 100 cc | Dry hide powder per 200 cc. |
|-------------------|-----------------------------|
| 0.35 — 0.45 grm.  | 9.0 — 11.0 grm.             |
| 0.25 — 0.35 „     | 6.5 — 9.0 „                 |
| 0.15 — 0.25 „     | 4.0 — 6.5 „                 |
| 0.00 — 0.15 „     | 0.0 — 4.0 „                 |

The mixture is filtered through linen, and squeezed, as under "Extracts (*i*)," and 100 cc. of the clear filtrate is evaporated to dryness and the residue weighed.

### IV. Evaporation and Drying.

(*o*) This must be done in a standard apparatus known as the "Combined Evaporator and Drier," at a temperature not less than 98°C. The time allowed for evaporation and drying is 16 hours.

(*p*) For evaporation and drying, flat-bottomed glass dishes, 2 $\frac{3}{4}$ " to 3" diameter, should always be used.

### Percentage of Tannin.

|                      |        |                          |        |
|----------------------|--------|--------------------------|--------|
| Chinese galls .. ..  | 70—77% | Alder bark .. ..         | 16—20% |
| Asiatic „ .. ..      | 55—60% | Mangrove bark .. ..      | 15—40% |
| Algarobilla .. ..    | 45%    | Bearberry .. ..          | 14%    |
| Catechu .. ..        | 40—50% | Babool bark .. ..        | 12—20% |
| Gambier .. ..        | 36—40% | Pistacia lentiscus .. .. | 12—19% |
| Divi-divi .. ..      | 30—45% | Oak bark .. ..           | 10—12% |
| Myrobalans .. ..     | 30—40% | Larch .. ..              | 9—10%  |
| Oak galls .. ..      | 25—34% | Willow bark .. ..        | 8—12%  |
| Sumach .. ..         | 25—27% | Hemlock fir .. ..        | 8—10%  |
| Mimosa bark .. ..    | 20—30% | Norway spruce .. ..      | 7—13%  |
| Canaigre .. ..       | 20—25% | Birch bark .. ..         | 3—5%   |
| Quebracho wood .. .. | 20%    | Beech bark .. ..         | 3—4%   |

## LEATHER ANALYSIS.

W. MATHER, Assoc.M.C.T., A.I.C.

The basic constituents of leather are hide fibre and combined tannins; a certain amount of uncombined tannins is essential to the quality of the leather. Chrome sole leather may contain as much as 40% of fats and waxes. Seasons and finishes may be present; for example, thin films of shellac or pyroxylin produce great water-resisting properties.

*Moisture.* 5 to 10 grm. of the finely-divided sample may be dried in an air-oven for 6 to 8 hrs. On account of the possible presence of oxidisable oils, moisture should preferably be calculated by difference after determination of soluble and insoluble materials.

*Ash.* 5 to 10 grm. of the finely-divided sample is incinerated in a tared dish until all carbon is removed.

The ash may contain calcium salts from the liming process, sodium and aluminium salts from the pickling process, chromium salts, and also salts of iron, tin, titanium, and antimony, used for the production of coloured material.

*Fats.* 25 grm. of the sample are extracted with petroleum ether (B.pt. 40°—60°C.) in a Soxhlet apparatus. The fats may be further investigated.

*Water soluble material.* The finely-divided leather is allowed to soak overnight in cold water, and is then extracted at 45°C. in a Proctor extractor, as used in the estimation of tannin materials. The solution is filtered, and a measured portion of the clear solution is evaporated, dried in the vacuum oven, cooled, and weighed. This gives the water soluble material, composed of non-tans, sugars, salts, and uncombined tannins.

The uncombined tannins may be determined in a measured portion of the aqueous extract by the method given in the "Tannin Materials" section.

Glucose may be determined as under Official American Method for Vegetable Tanned Leather (see later).

*Hide substance.* The nitrogen is determined in 0.7 grm. of the original leather by the Kjeldahl method, using 15 cc. of concentrated sulphuric acid and 10 grm. potassium sulphate. Hide substance contains 17.8% of nitrogen; 0.0034 grm.  $\text{NH}_3$  correspond to 0.01573 grm. of hide substance.

The nitrogen determination is affected by the presence of dyestuffs and of proteins used as seasons and finishes.

*Free mineral acid.* 3 grm. of leather is placed in 25 cc. of N/10 sodium carbonate solution in a platinum basin, and the liquid evaporated to dryness on a water-bath. The mass is then raised to a dull red heat until the leather is carbonised, when the residue is extracted with boiling water, and the insoluble material filtered off. The insoluble material is ignited and the ash treated with 25 cc. of N/10 hydrochloric acid; the filtrate is added to the previous aqueous extract. The solution is then titrated with N/10 alkali, using methyl orange or methyl red as indicator, and the alkali necessary is calculated as mineral acid, usually as sulphuric acid.

*Chrome determination.* This is carried out as under Provisional American Method for Analysis of Chrome Leather (see later).

## OFFICIAL AMERICAN METHOD FOR ANALYSIS OF VEGETABLE TANNED LEATHER.

(a) *Sample.* The sample of leather is reduced to a fine state of division by cutting or grinding.

(b) *Moisture.* 10 grams of leather are dried for 16 hours at a temperature of 95°—100°C.

(c) *Fats.* 5 to 10 grams of air-dried leather are extracted in a Soxhlet apparatus until free from grease, using petroleum ether boiling below 80°C. The ether is evaporated and leather dried to constant weight. Alternatively:—30 grams of leather are extracted as above, freed from solvent and used for the determination of water soluble materials.

(d) *Ash.* 10 to 15 grams of leather are incinerated in a tared dish at a dull red heat until free from carbon.

(e) *Water soluble material.* 3 grams of leather are digested in a percolater over night, then extracted with water at 50°C. for 3 hours. The total volume of solution should be 2 litres. Total solids and non-tannins are determined according to the Official Method for extract analysis.

(f) *Glucose.*

Copper sulphate. 34.639 grams of  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  are dissolved in distilled water, diluted to 500 cc., and filtered through asbestos.

Alkaline tartrate solution. 173 grams of Rochelle salt and 50 grams NaOH are dissolved in water, diluted to 500 cc. allowed to stand 2 days, and filtered through asbestos.

Normal lead acetate solution. A saturated solution of normal lead acetate.

Determination. 200 cc. of leather extract of analytical strength are placed in a 500 cc. flask, 25 cc. of a saturated solution of normal lead acetate added, the whole frequently shaken, and then filtered. To the filtrate is added an excess of potassium oxalate, the whole mixed for 15 minutes, and then filtered until clear. 150 cc. of clear filtrate are placed in a 600 cc. flask, 5 cc. of conc. HCl added, and boiled under a reflux condenser for 2 hours. The cooled solution is neutralized with anhydrous sodium carbonate, made to 200 cc. and filtered. The dextrose in the solution is then determined. 50 cc. of the clarified and neutralized solution are added to a mixture of 25 cc. of the copper sulphate solution and 25 cc. of the alkaline tartrate solution, heated to boiling in exactly 4 minutes, and boiled for 2 minutes longer. The solution is immediately filtered through asbestos, the precipitate washed thoroughly with hot water, then with alcohol, and finally with ether, dried for half-an-hour in a water oven and weighed as cuprous oxide, the amount of dextrose being determined by the use of Munson and Walker's table (Bull. 107, Revised, *American Bureau of Chemistry*, page 243).

(g) *Nitrogen*. Gunning modification of Kjeldahl method. using 0.7 gram of leather.

## PROVISIONAL AMERICAN METHOD FOR THE ANALYSIS OF CHROME LEATHER.

*Chrome Determination*. 3 grams of leather are ashed, the ash well mixed with 4 grams of a mixture of equal parts of sodium carbonate, potassium carbonate and powdered borax glass, and fused for 30 minutes. The mass is cooled, dissolved in hot water containing enough HCl to make the solution acid, and filtered. The filtrate is made up to 500 cc., 100 cc. of which are taken, 5 cc. HCl added, and the  $\text{Cr}_2\text{O}_3$  determined by titrating with N/10 sodium thiosulphate, using KI and starch as indicator. One cc. of N/10 thiosulphate is equivalent to 0.002533 gram  $\text{Cr}_2\text{O}_3$ .



## CELLULOSE AND PAPER.

C. F. CROSS, B.Sc., F.I.C., F.R.S.

The *raw materials* of the paper mill which require the control of the chemist are: (a) Vegetable fibrous materials, and (b) chemical agents used in the process of preparing these raw materials, and making the prepared fibre into paper or boards. Methods under (a) are special to the industry; those under (b) are for the most part those of general laboratory practice, *e.g.*, the analyses of waters, fuels, soda, soaps, bleaching powder, acids, sulphates of alumina, gelatin, and colouring matters.

(a) Raw fibrous materials are all of "natural" origin and include: (1) original products of plant life, *e.g.*, esparto, straw, Adansonia bast; (2) materials prepared and concentrated by mechanical treatment of the original forms, *e.g.*, flax and hemp, scutching waste, jute cuttings, cotton hull fibres; an important supply is in the form of (3) textile waste of all kinds from the spinning, rope and twine industries, cuttings of cotton, flax, and hemp cloths, and used fabrics of all kinds; lastly, a supply of equal importance takes the form of (4) "pulp," *i.e.*, a fibrous mass representing the essential useful structural elements of the plant or plant tissue separated and concentrated by chemical or mechanical treatment of original raw material, *e.g.*, wood pulps, straw half stuff, rag half stuff.

The standard method of investigating these raw materials, especially those of classes (1) and (2), is that devised by Cross and Bevan (*J.C.S.*, 1883, **43**, p. 25; compare *Rep. Ind. & Col. Exhib.*, London, 1886), which includes:

- (1) Estimation of moisture; the loss in weight at 100°C. is determined.
- (2) Inorganic matter (ash).
- (3) Oil, wax, resin, by continuous extraction in a Soxhlet apparatus with special solvents.
- (4) Alkaline hydrolysis. The material is boiled with 1 per cent. caustic soda solution for (a) 5 minutes, (b) 60 minutes, and the loss in weight due to the removal of hemicelluloses determined.
- (5) Cellulose estimation by chlorination method, following the alkaline hydrolysis.

In connection with paper-making, the main factors of value are the cellulose content, and the dimensions and form of the ultimate fibres.

### *Estimation of cellulose.*

Cellulose is relatively resistant to alkaline hydrolysis, to the action of chlorine gas, and to the action of oxidising agents, *i.e.*, to reagents which attack the hemicellulose, pectic compounds, lignone (and Cutose), which make up the "non-



cellulose" aggregate, associated with the celluloses in the natural fibrous products.

The cuticular elements of fibre-aggregates are fractional in amount, and generally negligible. In cases where they have to be taken into account, the special methods of König (*Zeitschr. Farb. Ind.*, 1911, 1912, Vols. 11, 12) should be studied, and also an investigation by the author, "Cutocellulose Composition and Constitution" (*J. Soc. Dyers and Col.*, 1919, **35**, 70).

The material is carefully sampled, weighed in the air-dried state,—the "moisture" being estimated in a blank sample, weighed at the same time,—and boiled in 10—15 parts by weight of 1 per cent. caustic soda solution at constant volume, for 10—60 minutes, according to the proportion (10—60 per cent.) and character (pectous or lignified) of the non-cellulose considered to be present.

The boiled fibrous mass is transferred to a cotton cloth filter, washed thoroughly, and well squeezed so that the fibre retains not more than its own weight of water. It is then detached, opened out, placed in a beaker, and exposed to a full atmosphere of well-washed chlorine gas for one hour. The residual chlorine is removed, and the fibre covered with a known volume of water; an aliquot portion of the solution is titrated, and the amount of hydrochloric acid formed calculated. This is a useful indirect measure of lignone in the sample. (See Cross and Bevan, "Cellulose," p. 104.) After washing from acid, the chlorinated fibre is placed in a 2 per cent. solution of sodium sulphite crystals, and slowly raised to the boil; 0.1 per cent. of caustic soda, calculated on the weight of the solution, is then added. This completes the removal of the soluble products. The fibre (cellulose) is then washed on a cloth filter, finally with a small amount of dilute acetic acid, water-squeezed, and opened out on a paper tray to dry.

It is sometimes necessary to repeat the chlorination as in the case of highly lignified aggregates, such as wood; but by intensifying the preliminary alkaline treatment the densest woods may be resolved in a single chlorination.\* The cellulose may retain small amounts of coloured bodies: these are easily removed by immersion in dilute hypochlorite, or in 0.05 per cent. permanganate, in both cases followed by a wash with sulphurous acid, and finally with water until neutral.

It may be remarked that in the alkaline treatment of raw materials as described above, iron boiling vessels may conveniently be used. With regard to filtration, it will be obvious that in many cases the fibre itself will act as a filter when

\* See also "The Determination of Cellulose," W. H. Dore, *J. Ind. Eng. Chem.*, xii, 264 (1920):

supported in an ordinary funnel; also that paper filters are inadmissible. There are advantages in the use of bleached cotton cloths, which may be either supported in funnels, or attached to rectangular wooden frames. Wire gauze, such as paper-makers' machine wire, may be used, in which case it is better to have a rectangular supporting frame of wood. Attention must be paid to the dimensions of the mesh. In washing a disintegrated mass which contains cellular celluloses of small dimensions (under 1 mm.), these are forced by careful washing through the wire gauze sieve, and separated from the fibres proper, *i.e.*, of dimensions 1-5 mm. and upwards.

#### *Ultimate fibres.*

The cellulose thus chemically isolated is invariably resolved into ultimate fibres. The dimensions of these are estimated by microscopic examination. Of particular importance are the lengths, and average length, which are constants of the celluloses.

For details of microscopic work and manipulations a standard hand book of histology must be consulted. (See also Cross and Bevan, "Papermaking," Chaps. 3 and 4.)

The following table shows the variations in length of ultimate fibres, and of the staple textile fibres :

|                                      | Length of Fibre. |  | Diameter.     |
|--------------------------------------|------------------|--|---------------|
|                                      | mm.              |  | mm.           |
| Fine textiles :                      |                  |  |               |
| Cotton                               | 20 — 40          |  | 0·012 — 0·037 |
| Flax                                 | 25 — 30          |  | 0·015 — 0·037 |
| Rhea                                 | 60 — 200         |  | 0·030 — 0·070 |
| Hemp                                 | 15 — 20          |  | 0·016 — 0·050 |
| Coarse textiles and<br>rope-making : |                  |  |               |
| Jute                                 | 1·5 — 4·0        |  | 0·020 — 0·025 |
| Sisal                                | 1·5 — 6·0        |  | 0·015 — 0·026 |
| Phormium                             | 5·0 — 15·0       |  | 0·010 — 0·020 |
| Paper-making only :                  |                  |  |               |
| Pinewood (tracheids)                 | 1·0 — 3·0        |  | 0·015 — 0·020 |
| Esparto                              | 0·5 — 3·0        |  | 0·010 — 0·018 |

All the above furnish staple raw materials for paper-making; it will be evident that the fibres of the first class occur in papers in the form of fractions of the natural individuals.

A more practical assay of cellulose imitates the conditions of mill treatment. The raw materials are treated with 10-20 per cent. of their weight of caustic soda, in the form of more concentrated solution, *e.g.*, of from 2 to 4 per cent. NaOH. Digestion may be at ordinary boiling temperature, in open iron vessels, or at temperatures up to 150°C. in digestors or autoclaves.

After the alkaline digestion, which may be studied in

gradually increasing concentrations until the optimum is reached, the mass is fully washed on wire gauze, filtered, thoroughly washed and squeezed. The whole is weighed and a fair sample, say 1/10 of the weight, is removed and dried, for yield of half-stuff. It is generally necessary to subject it to the *bleaching test*. For this a quantity of stock solution of bleaching powder, the "active chlorine" content of which is known, is taken, to contain from 10 to 20 per cent. of the weight of the cellulose half-stuff of original dry bleaching powder, and the volume of diluting water is such as to represent 20—30 times the weight of the half-stuff. The stuff is well stirred into the bleaching liquor to perfect mixture; the time is noted, and to determine the rate of exhaustion small quantities of liquor may be drawn off at different stages, and the residual chlorine determined. For the full test the material is left for about 16 hours in contact with the bleaching solution in the cold, and the residual chlorine then estimated.

The bleached cellulose is transferred to a cloth filter, washed with water and then with a small amount of dilute sulphurous acid, and again with water, and broken up to air-dry. The air-dried weight and the portion of the sample dried at 100°C., should give the weight of the actual cellulose.

It is found that the laboratory method of alkaline hydrolysis and chlorination gives higher yields of cellulose than the assay processes just described. This results from the fact that resistance to attack is a relative quality, and that in the more severe treatments in the latter process the celluloses are attacked and partly degraded to products soluble in alkaline liquors.

The celluloses as ultimate fibres are structural individuals of definite character, and are readily identified under the microscope, even when "beaten" to papermaking length (2–4 mm.). The cellulose of the gramineæ (esparto, straw, etc.) are distinguished by a colour reaction, becoming rose-red on boiling with a solution of aniline salt (hydrochloride). In admixture with other celluloses (cotton, wood, etc.), as in many papers, the depth of colour is an approximate measure of their proportion.

The following classification of the fibrous celluloses is generally adopted :

|                              | % Carbon. | % Furfural | Fehling's soln.         |
|------------------------------|-----------|------------|-------------------------|
| A. Cotton, flax, hemp, ramie | 44·0—44·4 | 0·2— 0·5   | no reduction.           |
| B. Wood (conifers)           | 43·0—43·5 | 2·0— 3·0   | slight reduction.       |
| C. Esparto                   | 44·0      | 12— 13     | slight reduction.       |
| D. Straws (cereals)          | 42·5—43·5 | 12— 13     | considerable reduction. |

The furfural is obtained by boiling with hydrochloric acid (Sp. Gr. 1.06), and estimated as phloroglucide (see "Text-Book of Paper Making, Cross and Bevan, 5th Edition"); the test with Fehling's solution is carried out with the diluted solution (1:5) at the boil.

The celluloses are fully oxidised to ultimate products (carbon dioxide and water) by chromic acid in presence of sulphuric acid. The carbon may therefore be estimated by the moist combustion method, in terms of chromic acid; or in presence of concentrated sulphuric acid the combustion may be carried out in connection with gas-measuring apparatus, and the carbon content calculated from the volume of gas evolved (*J.C.S.*, 1888, **53**, 889). Raw materials of the fourth class (see above) are mostly supplied to British paper-makers in the form of pulp, and in sheet or rolls. The pulp market is ruled by the convention of "air-dry pulp containing 10 per cent. moisture," and is usually delivered in the air-dry form; but to a certain extent as moist pulp with 50 per cent. moisture. In either case the actual moisture is a variable, and since the value of any parcel is that of its content of "air-dry, 10 per cent. moisture," it is always subjected to a moisture test. In this test the importance of sampling is paramount. The ruling convention is to draw sample bales, 2-4 per cent. of the total parcel; to cut from these a fair sample, and to re-sample this intermediate bulk for drying at 100°C. in the laboratory. The methods are those of experts, and special manuals must be consulted (see, for example, Sindall and Bacon, "The Testing of Wood Pulp").

The wood celluloses (pulp) are delivered unbleached and bleached. The former may require testing for bleaching capacity, *i.e.*, the proportion of bleaching powder consumed in bringing it to standard white. The general basis of such methods has been indicated above; for particulars and details the technical manuals should be consulted. (See above, "The Testing of Wood Pulp.") The bleached celluloses are for special purposes tested for the condition of the cellulose. By treatment with caustic soda these are resolved into:

- $\alpha$ -Cellulose, resistant to caustic soda
- $\beta$ -Cellulose, dissolved by caustic soda, and reprecipitated by acetic acid.
- $\gamma$ -Cellulose remains soluble in the acidified filtrate from  $\beta$ -cellulose.

The details of the method adopted are of less importance than rigorous uniformity of *all* the conditions of treatment, a method being devised according to the special purposes for which the pulp may be required.

As a further illustration of this point, it may be noted that

there is a wide divergence between a "normal pure cotton cellulose" and bleached cotton cellulose conforming with market standards, whether cloth, yarn or pulps ("rag"). The "normal" cellulose is required by the calico printers and by the makers of gun-cotton. The calico printers' test of the bleached goods is empirical, being based on their resistance to colouring matters in the dye-bath, notably to Alizarin. If degraded by hydrolysis or oxidation, cellulose develops an increasing affinity for colouring matters; hence, in dyeing mordant-printed cloths, the "whites" of the ground cloths are spoiled. A normal cotton cellulose answering such test, in the form of cloth, will show only a fractional loss of weight when mercerised, washed, soured, washed, and dried. Reputed pure cellulose, as, *e.g.*, "Swedish" filter-papers, are often found to lose 2-5 per cent. in weight, *i.e.*,  $\beta$  and  $\gamma$ -cellulose.

The normal cellulose of the specification for bleached cottons to be converted into cellulose nitrate (gun-cotton), is defined in negative terms as follows:

|   |                    |
|---|--------------------|
| Mineral matter  | Not to exceed 0.5% |
| Loss of weight on <i>boiling</i> with<br>3 per cent. solution of caustic<br>soda for 15 minutes                 | " " 3.0%           |
| Boiled with 1 part of Fehling's<br>solution and 2 parts of water<br>copper reduced (as $\text{Cu}_2\text{O}$ ). | " " 1.0%           |

*Oxycellulose*, *Hydrocellulose*, and *Hydrate-cellulose* are terms applied to cellulose derivatives, products of reactions with oxidants, acids, alkalis and certain salts. They are, however, not to be regarded as chemical individuals—whereas the normal cotton cellulose justifies such description in so far that it is homogeneous as a reacting aggregate (in synthetic reactions); the derivatives resulting from the attack of oxidants and acids are mixtures of degradation products.

In examining cellulose materials for the presence of these derivatives, the following typical characteristics are to be noted:

*Oxycelluloses*, as formed by the action of hypochlorous acid on cotton, have a marked affinity for basic dyes. The standard test, or rather method of diagnosis, is that of comparative dyeings in baths of Methylene blue of 1.0—0.1 per cent. concentration.

*Hydrocelluloses*, as formed by the action of halogen hydracids on celluloses, are structurally disintegrated, and the microscope reveals the brittle condition of the modified fibre substance. They are characterised by a much reduced (30—50 per cent.) affinity for atmospheric moisture. Like the oxycelluloses, they have the reactions of aldehydes.



*Hydrate-celluloses* are formed with visible hydration effects, as in mercerising with solutions of caustic soda (15—17 per cent. NaOH), or on heating with zinc chloride solution (50 per cent.  $\text{ZnCl}_2$ ). They are characterised by increased (20—30 per cent.) affinity for atmospheric moisture. They absorb cupric hydroxide from cold alkaline solutions, *e.g.*, Fehling's solution, but give no aldehyde reaction on boiling (reduction). The absorbed CuO may be quantitatively estimated by various and obvious methods, and is recognized as a measure of comparative states or degrees of hydration (Schwalbe).

The "wood pulps" include "mechanical" pulps, or wet-ground wood, composed therefore of the entire wood substance, or ligno-cellulose, less adventitious substances dissolved, and removed in the process of wet grinding, followed by running in suspension in water on the endless-running wire cloth of the machine.

The ligno-celluloses are highly reactive by virtue of their lignone components, which are unsaturated aldehydes and ketones. (See Cross and Bevan, "Cellulose," pp. 89—214.) They react not only with the halogens, but absorb large amounts of oxygen, and cannot be bleached with the ordinary bleaching agents, nor indeed at all, within economical limits. They combine with the synthetic colouring matters of the most varied constitutional types, and also with aromatic amines and phenols to form coloured derivatives. With the monamines (aniline, etc.) the products are yellow. More characteristic is the magenta coloured derivative formed with dimethyl-*p*-phenylenediamine; not only is the depth of colour considerable, but uniform for specimens of varied origin and history. As a "constant" therefore of the ligno-celluloses, it has been adopted as a quantitative measure of the proportion present in admixture with non-reacting celluloses, as in papers. Equally characteristic and intense is the red coloration with phloroglucinol, which is a reaction of condensation determined by hydrochloric acid; this is also used as an approximately quantitative measure.

All such processes depending upon judgment of colour intensity, are liable to error proportional to the percentage of reacting substance, and therefore to the colour intensity; only up to the proportion of 30 per cent. admixture with non-reacting celluloses is there a satisfactory approximation.

A reinvestigation of this reaction, however (Cross, Bevan and Briggs, *Ber.*, 1907, 40, 3119) has shown that the colour phase involves only about 10 per cent. of the total phenol reacting. It is a reaction of the aldehyde groups of the lignone, which are also those which react with amines. Quantitative estimations of the total phloroglucinol reacting showed that constant results are obtained, and therefore

furnish a method of estimating ligno-celluloses which is free from the defects above noted. In this method advantage is taken of the interaction of phloroglucinol with aldehydes, more particularly formaldehyde and furfuraldehyde, to give a volumetric process, as follows :

10 cc. of a solution containing 0.5 gram. of phloroglucinol per 100 cc. of hydrochloric acid (Sp. Gr. 1.06) are diluted with 20 cc. of hydrochloric acid of the same strength, and the liquid heated to 70°C. The standard aldehyde solution contains either 0.4 gram. of furfural or 0.2 gram. of 40 per cent. formaldehyde dissolved in 100 cc. hydrochloric acid (Sp. Gr. 1.06), and is added from a burette 1 cc. at a time, with an interval of two minutes between each addition. At 70°C. the reaction between the phenol and the aldehyde is complete within this time. Towards the end of the titration the aldehyde solution is added in decreasing quantities, but with the same interval between each addition. The course of the titration is followed by placing a drop of the liquid on a piece of ordinary newspaper (70—80 per cent. ligno-cellulose), a red stain being produced as long as the phloroglucinol is in excess. (The reaction is perceptible at a dilution of 1 in 30,000 of the phenol.) Near the end-point it is necessary to dry the spot at a gentle heat before the stain appears. For the estimation of the quantity of phloroglucinol reacting with a given ligno-cellulose or mixture, 2 gram. of the finely-divided material, fibre or paper, are dried at 100°C., weighed, placed in a dry flask, and covered with 40 cc. of the phloroglucinol solution. After standing for about 16 hours the liquid is strained through a small plug of cotton wool, and 10 cc. are taken for titration. The difference between the two titrations gives the quantity of phloroglucinol reacting with the ligno-cellulose. This is expressed as a percentage on the dry fibre substance. In the analysis of papers, the fibre substance is estimated approximately by deducting the weight of the mineral matter (ash) and 1.5 per cent. for sizing constituents from the dry weight of the paper. The following numbers have been determined :

*Phloroglucinol absorption values as percentage of dry fibre.*

|                                 |     |     |     |     |     |      |
|---------------------------------|-----|-----|-----|-----|-----|------|
| Wood flour                      | ... | ... | ... | ... | ... | 7.50 |
| Mechanical wood-pulp            | ... | ... | ... | ... | ... | 6.71 |
| Jute (best white)               | ... | ... | ... | ... | ... | 3.98 |
| Jute (ordinary)                 | ... | ... | ... | ... | ... | 4.23 |
| Sulphite wood-pulp              | ... | ... | ... | ... | ... | 0.75 |
| Esparto cellulose               | ... | ... | ... | ... | ... | 0.50 |
| Cotton                          | ... | ... | ... | ... | ... | 0.20 |
| Hydro-cellulose from cotton     | ... | ... | ... | ... | ... | 0.42 |
| Hydro-ligno-cellulose from jute | ... | ... | ... | ... | ... | 4.54 |



The *chemical* examination of papers is a subordinate matter. Quality and value are determined more by fibre composition, which is ascertained by microscopic analysis,\* and by physical constants, which can be tested and expressed in numerical terms, such as breaking strain, elasticity, bursting strain, specific volume, etc. The composition of pulp or pulp "furnish," determined by microscopic examination may be controlled by the chemical constants of the component fibre substances, *e.g.*, by determination of yield of furfural on boiling with hydrochloric acid (Sp. Gr. 1.06). In mixtures containing ligno-celluloses these are estimated by one of the methods above described.

(b) NON-FIBROUS COMPONENTS OF PAPER. The adventitious constituents of general importance are : mineral matter, sizing constituents, and, in coloured papers, the colouring agents employed.

*Mineral matter* is determined as total ash, which may be the natural ash of the fibre components, or added loading matter, *e.g.*, china clay in papers of medium quality, calcium sulphate in higher class writing papers, barium sulphate (*blanc-fixe*) and *satin white* (alumina and calcium sulphate) in coated art papers. These are identified or estimated by the usual systematic analytical methods.

For the identification of *colouring matters* and *pigments* the section on "Dyestuffs" is to be consulted.

*Sizing agents.* Starch may be identified by the usual reaction with iodine. Resin, or resin acids, are detected by extraction with alcohol-ether containing a small amount of acetic acid; on pouring into water the dissolved resin acids form an emulsion. In estimating the quantity, which, however, is seldom necessary, the paper can be extracted in a continuous extraction apparatus, the residue isolated and weighed.

In tub-sized papers, which may contain from 2 to 9 per cent of gelatin, the estimation of gelatin is usually carried out in terms of total nitrogen by the Kjeldahl method. A more rapid process depends upon the reaction of the amino-groups of gelatin with chlorine in constant proportion to form chloroamines, the chlorine of which reacts as hypochlorite chlorine, and may be conveniently estimated by means of standard arsenite solutions (*J. Soc. Chem. Ind.*, 1908, **27**, 260).

\* Recent researches (Spence and Krauss) have established relative weights of fibres for unit dimensions by optical estimation (*Paper Making*, Cross and Bevan, Fifth Edition, p. 414).

## TEXTILE FIBRES.

W. F. A. ERMEN, M.A.

### METHODS OF DISTINGUISHING ANIMAL AND VEGETABLE FIBRES.

The material to be examined is boiled alternately with very dilute sodium carbonate and hydrochloric acid until organic finishing matters have been removed; it is then well washed, dried, and the following tests carried out:

(1) On ignition in a porcelain crucible vegetable fibres evolve vapours which are acid to litmus and have the odour of burning wood. The carbonaceous residue rapidly burns away, leaving only a trace of light ash. On similar treatment, animal fibres melt, give off alkaline vapours with the smell of burning feathers, and leave a lustrous residue of carbon which burns away very slowly.

(2) The vegetable fibres are not visibly affected by boiling in 10% caustic soda solution, whereas animal fibres are rapidly disintegrated and dissolved.

(3) Lead acetate solution is cautiously added to a hot solution of caustic soda until a permanent precipitate is just produced. The solution is cooled and filtered, and the material shaken with it, when wool fibres slowly become brown, due to the deposition of lead sulphide in the body of the fibres; all other fibres remain colourless.

(4) To distinguish between cotton, linen and artificial silk the fibres are teased out, mounted in water and examined under the microscope. The importance of having available a set of fibres of known origin for comparison under the microscope cannot be too greatly emphasised.

Cotton fibres form translucent, twisted ribbons, somewhat thickened along the edges. After mercerisation the fibres are rather more rounded and less twisted.

Linen fibres appear as straight, transparent tubes, with characteristic swellings, which appear like the joints on a bamboo cane.

Artificial silk fibres are almost cylindrical and absolutely structureless, like glass rods.

Jute, hemp, ramie and other vegetable fibres are most easily recognised by means of their microscopic structure, but even this method of identification is difficult.

The hemp fibre closely resembles the linen fibre, but it is coarser and less lustrous. It is generally met with in the form of rope, cordage, and canvas, and sometimes woven with linen.

Jute fibres are yellowish white, and appear under the microscope as bundles of lustrous cylinders, somewhat irregular in thickness. It is a ligno-cellulose, and not a true cellulose, and hence exhibits considerable affinity for basic dyestuffs.

Ramie (China-grass) fibres are composed of pure cellulose; they differ from cotton in being softer and more lustrous. Well-marked characteristics are the pointed ends of the fibres and the bold longitudinal striations.

Data regarding the length and diameter of textile fibres will be found under the "Cellulose and Paper" section.

Chemical tests have been proposed, but are all somewhat uncertain and apt to be misleading; colour reactions are unreliable, owing to varying treatment of the fibres in degumming, scouring, bleaching, dyeing, mercerising, etc.

(5) True silk is almost instantly soluble in cold concentrated hydrochloric acid, whereas Tussah silk is only affected after 48 hours. This reaction may be used quantitatively. On examination under the microscope, silk in the gum will show twin fibres.

(6) Diphenylamine dissolved in pure sulphuric acid gives the following colorations:

|  |                |
|--|----------------|
| True silk .. .. .                                      | Brown.         |
| Tussah silk .. .. .                                    | Intense brown. |
| Chardonnet and Lehner silk (Nitrocellulose process) .. | Intense blue.  |
| Pauly and Thiele silk (Cuprammonium process) ..        | No reaction.   |
| Viscose silk .. .. .                                   | No reaction.   |

#### ANALYSIS OF FABRICS CONTAINING SILK, WOOL AND COTTON.

*Moisture.* About 5 gm. of the sample are weighed accurately and dried at 100°C.

*Weighting materials.* The sample is steeped in a cold 1% caustic soda solution, washed, and boiled for 15 minutes in 2% hydrochloric acid. These operations are repeated until nothing further appears to be removed, when the sample is well washed, dried, and weighed. In case the sample contains silk a portion of the extracted material is then ignited, and the percentage of ash determined. If more than 1% of ash is found, the sample should be further extracted with warm 1% sodium carbonate solution, followed by boiling with a 1% solution of hydrofluoric acid in a platinum basin.

*Silk.* This is removed by treating the sample with a cold ammoniacal solution of nickel hydroxide. The residue is filtered, washed with hot 1% hydrochloric acid, washed with water, and dried.

*Ammoniacal nickel solution.* 25 gm.  $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$  are dissolved in 100 cc. of water, and caustic soda solution added until almost all the nickel is precipitated. The nickel hydroxide is filtered off, thoroughly washed, transferred with 125 cc. water into a flask, and 125 cc. of strong ammonia added.

*Wool and Cotton.* The residue from the silk estimation is boiled for 10 minutes with a 2% solution of caustic soda, filtered, and washed until free from alkali. The residue of pure cellulose is dried and weighed. The loss in weight is the amount of wool in the sample.

## COAL TAR.

W. H. COLEMAN, F.I.C.

The nature of tar depends upon the kind of coal carbonised, the design of the retort or oven, the temperature of carbonisation, the rate at which that temperature is attained and the length of time during which the volatile products are exposed to that temperature. Low temperatures, slow heating and rapid removal of the volatile products favour the formation of aliphatic hydrocarbons; high temperatures, rapid heating and a longer exposure of the volatile products to high temperature tend, on the other hand, to the formation of aromatic hydrocarbons. Recent research seems to indicate that aliphatic bodies are first formed, which on exposure to temperatures above  $700^{\circ}\text{C}$ . are converted into aromatic compounds with liberation of hydrogen.

The chief sources of coal tar are horizontal, inclined and vertical retorts at gasworks, coke ovens, blast furnaces, producers using bituminous coal, and recently some types of low temperature carbonising processes. The raw tar contains considerable but varying proportions of ammoniacal liquor and free carbon. After separating as much of the former as possible the tar is distilled. The fractions obtained vary considerably, the changes are made either by the temperature of the vapour or by the specific gravity of the distillate. Three examples of methods of fractionating follow :—

### I.

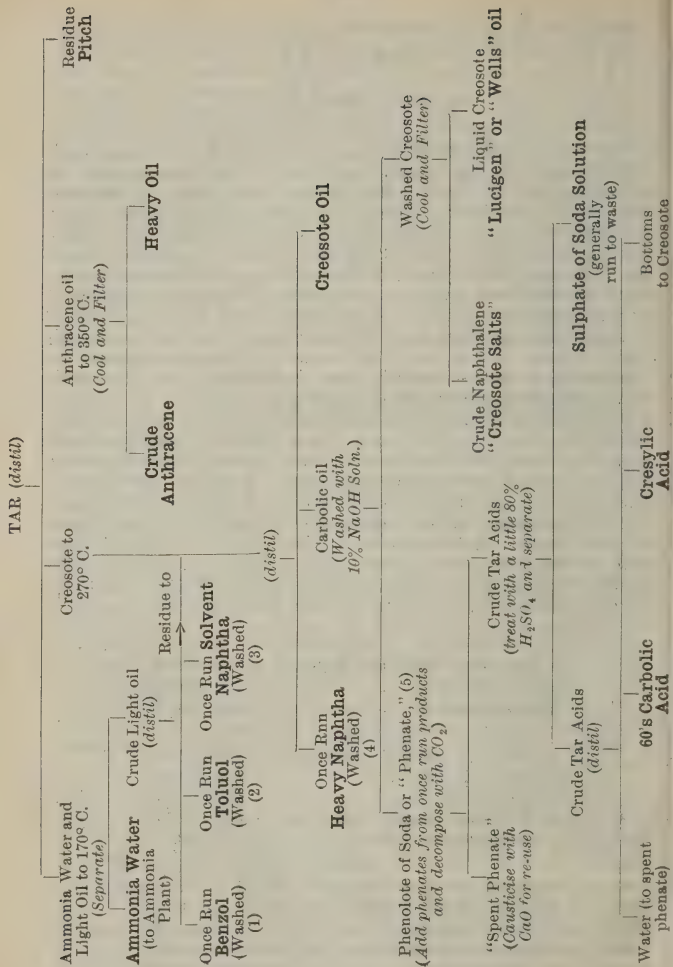
1. Ammonia water and light oil up to  $170^{\circ}\text{C}$
2. Creosote from .....  $170^{\circ}$ — $270^{\circ}\text{C}$ .
3. Anthracene oil .....  $270^{\circ}$ — $350^{\circ}\text{C}$ .

### II.

1. Ammonia water & crude naphtha up to  $110^{\circ}\text{C}$ .
2. Light oil from.....  $110^{\circ}$ — $200^{\circ}\text{C}$ .
3. Carbolic oil .....  $200^{\circ}$ — $240^{\circ}\text{C}$
4. Heavy or creosote oil.....  $240^{\circ}$ — $270^{\circ}\text{C}$ .
5. Anthracene oil above .....  $270^{\circ}\text{C}$ .

### III.

1. Ammonia water and crude benzol till water ceases.
2. Light oil till distillate has  $2^{\circ}\text{Tw. at } 80^{\circ}\text{F}$ .
3. Light creosote to.....  $8^{\circ}\text{Tw. at } 100^{\circ}\text{F}$ .
4. Heavy creosote to .....  $14^{\circ}\text{Tw. at } 100^{\circ}\text{F}$ .
5. Anthracene oil to .....  $18^{\circ}\text{Tw. at } 120^{\circ}\text{F}$ .



The fractions are subsequently treated in various ways, according to the quality of the tar and the final products desired. One method is outlined on the preceding page.

1, 2, 3, 4 are separately washed, first with NaOH solution, and the phenate added to (5); then with weak  $H_2SO_4$ , and the separated pyridine sulphate solution decomposed with ammonia to obtain ammonium sulphate and crude pyridine; then with concentrated  $H_2SO_4$  to remove thiophene and unsaturated hydrocarbons, after which the oils are washed several times with water, once with dilute NaOH, and finally with water. The washed oils are then fractionally distilled to obtain various qualities of benzol, toluol, solvent and heavy naphtha.

Crude tars differ very considerably in composition, as will be seen from the table on the following page.

In order to give some approximate idea of the final products to be expected, the working results from over 200,000 tons of mixed Lancashire tars are given below:—

|                                | Per cent. on tar. |     |                    |
|--------------------------------|-------------------|-----|--------------------|
| Benzol, 90% at 100°C.          | ...               | ... | 0.5                |
| Toluol, 90% at 120°C.          | ...               | ... | 0.2                |
| Solvent naphtha, 90% at 160°C. | ...               | ... | 0.6                |
| Heavy naphtha                  | ...               | ... | 0.2                |
| Pyridine 90% at 140°C.         | ...               | ... | 0.06               |
| 60's carbolic acid             | ...               | ... | 1.4                |
| Cresylic acid                  | ...               | ... | 0.9                |
| Naphthalene                    | ...               | ... | 1.3                |
| 30% anthracene                 | ...               | ... | 0.7                |
| Creosote and heavy oil         | ...               | ... | 22.2               |
| Pitch (medium)                 | ...               | ... | 68.6               |
| Ammonia water and loss         | ...               | ... | 3.34               |
|                                |                   |     | <hr/> 100.00 <hr/> |

A table which follows gives an idea of the properties of the various products generally made. The tests were made in each case by distilling 100 ccm. of an average sample from a side-tube flask with the top of the mercury bulb of the thermometer level with the side tube. No corrections were made for the emergent stem or for barometric pressure. All figures in table, except for specific gravities, are degrees Centigrade.



| No. | Description of Tar.                 | 1<br>Sp. Gr. | 2<br>Free<br>carbon | 3<br>%<br>Water | 4<br>%<br>distill-<br>ate to<br>170°C. | 5<br>%<br>distill-<br>ate to<br>270°C. | 6<br>%<br>distill-<br>ate 270°<br>- 350°C | 7<br>%<br>Pitch | Remarks   |
|-----|-------------------------------------|--------------|---------------------|-----------------|--|--|---|-----------------|---|
| 1.  | Horizontal retorts .....            | 1.217        | 22.0                | 3.9             | 3.4                                    | 14.0                                   | 15.1                                      | 67.5            | From large gas works,<br>high heats.  |
| 2.  | " .....                             | 1.185        | 14.7                | 2.5             | 4.1                                    | 22.0                                   | 19.5                                      | 54.4            | Moderate size works,<br>medium heats.   |
| 3.  | " .....                             | 1.125        | 6.9                 | 4.0             | 13.4                                   | 20.8                                   | 17.7                                      | 51.1            | Small works, compara-<br>tively low heats.  |
| 4.  | Inclined retorts .....              | 1.143        | 2.6                 | 2.0             | 9.2                                    | 23.5                                   | 17.9                                      | 49.4            | Contains no benzol but<br>much higher cresols<br>and some paraffin.<br>Much benzol and toluol<br>but no phenols.<br>Much paraffin bodies. |
| 5.  | Vertical retorts .....              | 1.108        | 2.4                 | 3.8             | 10.1                                   | 21.4                                   | 16.6                                      | 51.9            |   |
| 6.  | Coke ovens .....                    | 1.147        | 4.0                 | 2.0             | 4.1                                    | 24.2                                   | 18.7                                      | 53.0            |   |
| 7.  | Mond Producer .....                 | 1.150        | —                   | 16.0            | 0.7                                    | 19.9                                   | 33.7                                      | 45.7            |   |
| 8.  | Water gas .....                     | 1.030        | 2.3                 | 6.2             | 12.6                                   | 40.1                                   | 19.6                                      | 27.7            | See Note B.   |
| 9.  | Horizontal retorts, cannel coal.... | 1.080        | 4.5                 | 5.0             | 13.2                                   | 29.4                                   | 23.2                                      | 34.2            |   |
| 10. | " " Lancs. coal ..                  | 1.222        | 21.6                | 4.0             | 4.7                                    | 11.9                                   | 17.7                                      | 65.7            |   |
| 11. | " " Durham coal ..                  | 1.205        | 17.3                | 4.5             | 4.6                                    | 16.7                                   | 10.4                                      | 68.3            |   |
| 12. | " " S. Yorks. coal                  | 1.220        | 23.2                | 6.0             | 1.5                                    | 10.6                                   | 16.0                                      | 71.9            | See Note B.   |
| 13. | Coke ovens, W. Cumberland coal..    | 1.170        | 4.7                 | 2.0             | 2.0                                    | 21.4                                   | 18.4                                      | 58.2            |   |
| 14. | " " Yorkshire coal .....            | 1.115        | 2.1                 | 1.5             | 5.0                                    | 31.0                                   | 20.2                                      | 43.8            |   |
| 15. | " " Lancashire coal ....            | 1.155        | 5.4                 | 2.5             | 4.5                                    | 21.5                                   | 17.4                                      | 56.6            |   |
| 16. | Av. of about 30 Lancashire tars..   | 1.205        | 19.3                | 4.5             | 5.2                                    | 16.7                                   | 16.7                                      | 61.4            |   |

NOTE A.—For the sake of comparison the figures in columns 4, 5, 6 and 7 have been calculated on 100 parts of total distillate and pitch.

NOTE B.—Coke oven tar No. 14 is suspicious; it has probably been mixed with spent wash oil, as is sometimes done.

NOTE C.—It must be remembered that tars are liable to vary from many causes and the above results must be looked upon simply as a guide.



# Properties of Tar Products.

| Substance                | Sp. gr. at 1st<br>60° F. drop |       | 10%   | 20%   | 30%   | 40%   | 50%   | 60%   | 70%   | 80%   | 90%   | dry   | Remarks.                            |
|--------------------------|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------------------------------------|
| "Pure" benzol .....      | .884                          | 79.8  | 80.1  | 80.1  | 80.1  | 80.1  | 80.1  | 80.1  | 80.1  | 80.1  | 80.1  | 80.6  |                                     |
| "Pure" toluol .....      | .868                          | 110.7 | 111.3 | 111.3 | 111.3 | 111.3 | 111.3 | 111.3 | 111.3 | 111.3 | 111.3 | 111.7 |                                     |
| 90's benzol .....        | .877                          | 81    | 83.5  | 84    | 85    | 85    | 85    | 87    | 88    | 91.5  | 99    | 111   |                                     |
| 50's/90's benzol .....   | .873                          | 86    | 91    | 92    | 93.5  | 95    | 97    | 99.5  | 103   | 109.5 | 119.5 | 142   | (See paragraph<br>in text.)         |
| 90's toluol .....        | .868                          | 103   | 109   | 109.5 | 110   | 110.5 | 111   | 112   | 112.5 | 114   | 118   | 133   |                                     |
| 90/160 Solvent naphtha   | .871                          | 116   | 123   | 126   | 128   | 131   | 133   | 137   | 140.5 | 146   | 155   | 176   |                                     |
| 90/190 Heavy naphtha..   | .898                          | 151   | 159.5 | 162   | 163   | 165   | 167   | 169   | 171   | 175   | 181   | 194   |                                     |
| 65/120 Recovered coke .. | .895                          | 74    | 85    | 88.5  | 91    | 94    | 98    | 104   | 116.5 | 148   | 196.5 | 220   |                                     |
| oven benzol              |                               |       |       |       |       |       |       |       |       |       |       |       |                                     |
| Crude benzol .....       | .938                          | 74    | 103   | 115   | 126   | 140   | 158   | 179   | 194   | 215   | 243   | 308   | 5% Tar acids.<br>2% Crude pyridine. |
| Light oil .....          | 1.016                         | 143   | 176   | 187   | 194   | 200   | 206   | 211   | 218   | 225   | 243   | 308   | 18% Tar acids.<br>5% Crude bases.   |
| Light creosote .....     | 1.037                         | 146   | 203   | 210   | 217   | 223   | 231   | 240   | 253   | 274   | 313   | 357   | 17% Tar acids.<br>5% Crude bases.   |
| Heavy creosote .....     | 1.065                         | 196   | 232   | 246.5 | 258.5 | 269   | 282.5 | 301.5 | 319   | 336.5 | 360   | 390   |                                     |
| Anthracene oil .....     | 1.110                         | 210   | 270   | 292   | 305   | 316   | 326   | 338   | 351   | 366   | 394   | >400  |                                     |
| 60's Carbolic acid.....  | 1.057                         | 101   | 122   | 170   | 184   | 185   | 185   | 186   | 187   | 188   | 191   | 201   | 14% water.                          |
| 97/99 Cresylic acid..... | 1.045                         | 183   | 192   | 192.5 | 193   | 193   | 194   | 195   | 196   | 198   | 200.5 | 206   |                                     |
| 90/140 Pyridine .....    | 0.978                         | 98    | 102.5 | 105.5 | 112   | 117   | 122.5 | 125   | 127   | 131   | 137   | 153   | 5% water.                           |

## Benzols and Naphthas. (Weiss).

|                                | Boiling point.<br>°C. | Sp. gr. at<br>15° C. | Flash point<br>°F. | Evaporation<br>Test.* |
|--------------------------------|-----------------------|----------------------|--------------------|-----------------------|
| Benzol, pure                   | 80°-82°               | .881-.884            | below 32°          | 10 minutes            |
| " 100%                         | 100% at 100°          | .875-.884            | "                  | 13½ "                 |
| " 90%                          | 90% at 100°           | .875-.882            | "                  | 14 "                  |
| " 50%                          | 50% at 100°           | .871-.875            | "                  | 23 "                  |
| Toluol, pure                   | 110°-112°             | .869-.871            | "                  | 29 "                  |
| " commercial                   | 90% at 120°           | .869-.872            | "                  | 33 "                  |
| Xylol, pure                    | 135°-145°             | .865-.867            | 85°-5              | 89 "                  |
| Solvent naphtha or benzol 160° | 90% at 160°           | .864-.870            | 78°                | 107 "                 |
| Benzol, straw colour           | like 90's benzol      | .862-.870            | below 32°          | 18 "                  |
| Toluol, straw colour           | like coml. toluol     | .862-.870            | "                  | 36 "                  |
| Crude solvent naphtha          | like solvent naphtha  | .876-.887            | 78°                | 121 "                 |
| Heavy naphtha                  | about 85% at 200°     | .925-.940            | 109°               | 303 "                 |

\* Time taken for 2 ccm. to evaporate from metal surface 3½ inches square.

## Percentage Composition of Commercial Benzols. (Frank).

|                   | Benzene. | Toluene. | Xylenes. | Cumenes. | Naphtha-<br>lene. |
|-------------------|----------|----------|----------|----------|-------------------|
| 90's Benzol       | 84       | 13       | 3        | 0        | 0                 |
| 50's „            | 15       | 75       | 10       | 0        | 0                 |
| 30's „            | 43       | 46       | 11       | 0        | 0                 |
| Solvent naphtha I | 0        | 5        | 70       | 25       | 0                 |
| „ „ II            | 0        | 0        | 35       | 60       | 5                 |
| Heavy naphtha     | 0        | 0        | 5        | 80       | 15                |

Solvent naphtha I, to 160° C.

Solvent naphtha II, to 175° C.

## Methods of Testing Tar Products.

It must be borne in mind that nearly all tar tests are physical and not chemical, and, further, many are purely empirical and designed by purchasers to suit their own requirements. In America the Barrett Company have published a small book on Methods of Analysis of the Coal Tar Industry drawn up by a committee of their chemists. It is not entirely applicable to conditions in this country, and, sooner or later, the matter must be taken up by the industry in this country and a set of standard methods agreed upon. For the above reasons the methods following, whilst mostly in general use, are not accepted universally.

### CRUDE TAR.

*Sampling.* Owing to its viscous nature the only satisfactory method is to take samples at frequent intervals as the tar is flowing from one vessel to another. The samples are to be thoroughly mixed and a final sample taken from the mixture without delay.

*Specific gravity.* For most purposes this is taken with Twaddell's hydrometer, the tar being warmed slightly to render it less viscous. A more accurate method is to weigh a dry, empty 250 cc. graduated flask (W 1), fill it to within a few centimetres of the graduation with tar, using a long funnel, and taking care that the neck of the flask above the graduation is not soiled. The flask and tar are then weighed (W 2). The flask and tar are then allowed to assume the temperature of the balance room, and then filled to the mark

with distilled water and weighed again (W 3). The flask is then cleaned, filled to the mark with distilled water at the temperature of the balance room and weighed again (W 4). Then

$$\text{Sp. gr.} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

*Water.* 100 ccm. of the well-mixed sample is distilled, preferably from a copper flask, up to a temperature of 200°C. The distillate is caught in graduated cylinders and the volume of water read off after cooling. If separation is difficult a few ccm. of *dry* benzol added to the distillate will generally do away with any trouble. If the tar tends to boil over the flask should be heated at the side only and from 50 to 100 cc. of *dry* heavy naphtha or cresylic acid may be added to the tar before distillation.

*Free carbon.* 10 grammes of the sample are placed in a flask and 25 ccm. of glacial acetic acid and 25 ccm. toluene are added. The flask is warmed to 100°C. and well agitated, the contents filtered through a double, balanced filter, and washed with boiling benzol until the filtrate runs through colourless. The filter, together with its contents, is dried at 100°C. and weighed, the outer filter being used as a tare.

Laboratory tests of tar for yield of products are not satisfactory. The only way to obtain a real insight into the value is to distil 10—15 tons on the large scale, measuring, weighing and testing the fractions obtained. If, however, it is absolutely imperative to make a laboratory test, *at least* 2,000 grammes should be distilled from a copper flask, making the fractions in the same way as on the works and measuring, weighing and testing them. For purely comparative purposes and to check deliveries, 100 ccm. of the well-mixed average sample may be distilled from a side tube flask, with the thermometer bulb in the vapour, noting the percentages of distillate at 170°, 270° and 350°C., reading off the water and weighing the pitch.

CRUDE BENZOLS AND LIGHT OILS are tested for specific gravity and for percentage of tar acids. The latter test is made by washing 100 cm. of the sample with an excess of 10% NaOH solution and noting the contraction, or the phenate solution may be separated, decomposed with dilute  $\text{H}_2\text{SO}_4$  and the liberated tar acids measured.

*Test for yield of finished products.* 100 ccm. of the sample

is distilled from a retort up to a temperature of  $193^{\circ}\text{C}.$ , the bulb of the thermometer being  $\frac{3}{8}$  in. from bottom of retort. The measured distillate is then washed as follows:—(1) With about 50 cc. 10% NaOH solution, (2) with water, (3) with 4% of its volume of  $168^{\circ}\text{Tw. H}_2\text{SO}_4$ , (4) with 4% more  $\text{H}_2\text{SO}_4$ , (5) with a very small quantity of water run down the side so as to avoid forming an emulsion, (6) a repeat of (5), (7) with a large water wash, (8) with about 20 ccm. of 10% NaOH, (9) with several water washes until neutral. The oil is then separated and re-measured, the difference being reported as loss on washing. The washed oil is then fractionated, using four Le Bel Henniger bulbs or other equally efficient column, and the following fractions collected separately: Benzol up to  $101^{\circ}\text{C}.$ , toluol to  $121^{\circ}\text{C}.$ , solvent naphtha to  $166^{\circ}\text{C}.$ , and heavy naphtha to  $195^{\circ}\text{C}.$  The products may be taken as approximately of 90% quality.

**BENZOL, TOLUOL AND NAPHTHAS.** The commercial test for these products is carried out by distilling 100 ccm. from a glass retort with the bulb of the thermometer  $\frac{3}{8}$  in. from the bottom.

90's benzol should give 90% distillate at  $100^{\circ}\text{C}.$

90's toluol should give 90% distillate at  $120^{\circ}\text{C}.$

50's/90's benzol should give 50% at  $100^{\circ}$  and 90% at  $120^{\circ}\text{C}.$

90's/160's solvent naphtha should give 90% at  $160^{\circ}\text{C}.$

Heavy naphtha should give 90% at  $190^{\circ}\text{C}.$

*Pure benzol and pure toluol* are distilled from a flask, using a standard thermometer graduated in  $1/5$  or  $1/10^{\circ}\text{C}.$  100 ccm. is measured out in a graduated cylinder and poured into the flask, and distillation carried out at the rate of about one drop per second, using the same cylinder, without cleaning, as receiver, and noting the temperature when the first drop leaves the end of the condenser, when 3 ccm. have collected in the receiver and when the flask is dry. When cool the residue in the flask is poured into the cylinder and the defect from 100 ccm. is noted as loss. The difference in temperature between the 3 ccm. and the dry point should be less than  $0.5^{\circ}\text{C}.$

*Percentage of benzol and toluol in commercial samples* may be estimated by Dr. Colman's method (*J.S.C.I.*, 1915, p. 168, and 1919, p. 57).

The fractionation is carried out in a standard apparatus and the percentages distilling below  $105^{\circ}\text{C}.$  and above  $117^{\circ}\text{C}.$  noted. The percentage of toluene in the sample is ascertained from a table which is given in an abbreviated form.

# Percentage of Toluene in Commercial Toluol. (Colman).

Percentage boiling below 105°C.

| 5  | 8  | 11 | 14 | 17 | 20 | 23 | 26 | 29 | 32 | 35 | 38 | 41 | 44 | 47 | 50 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 50 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 47 | 52 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 44 | 54 | 50 |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 41 | 57 | 53 | 51 |    |    |    |    |    |    |    |    |    |    |    |    |
| 38 | 60 | 56 | 54 | 52 | 50 |    |    |    |    |    |    |    |    |    |    |
| 35 | 62 | 58 | 57 | 55 | 53 | 51 |    |    |    |    |    |    |    |    |    |
| 32 | 64 | 61 | 60 | 58 | 56 | 54 | 52 | 50 |    |    |    |    |    |    |    |
| 29 | 67 | 64 | 63 | 61 | 59 | 57 | 55 | 53 | 52 | 50 |    |    |    |    |    |
| 26 | 69 | 67 | 65 | 63 | 62 | 60 | 58 | 57 | 55 | 53 | 51 |    |    |    |    |
| 23 | 72 | 70 | 68 | 66 | 64 | 63 | 61 | 60 | 58 | 57 | 55 | 53 | 52 |    |    |
| 20 | 74 | 73 | 71 | 69 | 67 | 65 | 64 | 63 | 61 | 60 | 58 | 57 | 55 | 53 | 51 |
| 17 |    | 75 | 72 | 71 | 69 | 68 | 67 | 65 | 64 | 63 | 62 | 60 | 58 | 57 | 55 |
| 14 |    |    | 74 | 73 | 72 | 71 | 69 | 68 | 67 | 66 | 65 | 63 | 62 | 61 | 59 |
| 11 |    |    |    | 75 | 74 | 73 | 72 | 71 | 70 | 69 | 67 | 66 | 65 | 64 | 63 |
| 8  |    |    |    |    |    | 75 | 74 | 73 | 72 | 72 | 71 | 70 | 68 | 67 | 66 |
| 5  |    |    |    |    |    |    | 74 | 73 | 75 | 75 | 74 | 73 | 72 | 71 | 70 |

Percentage boiling above 117°C.







*Estimation of sulphur in benzol, toluol, etc.* A measured quantity of the benzol is mixed with ten times its volume of 90% alcohol (free from sulphur) and burned in a spirit lamp under the trumpet tube of a Gas Referee's Sulphur in Coal Gas apparatus. When the lamp has burned out a further quantity of the alcohol is added and burned to ensure that all sulphur has been consumed. The condenser of the apparatus is washed out and the sulphur after oxidation by bromine is precipitated by  $\text{BaCl}_2$ .

*Flash point* is taken in the Abel closed test apparatus, a freezing mixture of snow or crushed ice and salt taking the place of the water in the bath in the case of benzol and toluol.

COMMERCIAL PYRIDINE is examined for colour, reaction with cadmium chloride and with Nessler's reagent, for boiling point, miscibility, percentage of water and titration with  $\text{H}_2\text{SO}_4$ .

60's CARBOLIC ACID (*Lowe's test*). 100 ccm. are distilled from an 8 oz. retort having a neck about 15 inches long. No condenser is used and the distillation is so conducted that it lasts about two hours. Reject the first 10 ccm. of oil which distills over along with the water, which must not exceed 15 ccm. Then collect the next 62.5 ccm. in a dry cylinder. The 62.5 cc. are well mixed and cooled, stirring with a thermometer all the time. When near the expected crystallising point (usually  $60^\circ\text{F.}$ ) a small crystal of pure phenol is added, and the temperature is noted when the distillate is crystallised throughout. A Fahrenheit thermometer divided in  $1/10^\circ$  is used. Carboic acid is also tested for sp. gr. and for solubility in caustic soda solution of sp. gr. 1.100.

CRESYLIC ACID (*liquid carboic acid*) is tested for sp. gr., for percentage of water, for solubility in 1.100 caustic soda solution and for distilling point. The last test is generally made in a flask with the bulb of the thermometer in the vapour; 95 per cent. should distil between  $195^\circ$  and  $205^\circ\text{C.}$  Cresylic acid for soap makers should not give a pink or dark-brown colour with  $\text{NaOH}$  solution, and should be free from sulphur compounds.  $\text{H}_2\text{S}$  is detected by passing a current of air through the warmed sample and causing the air to impinge on a piece of lead acetate paper.

*Hydrocarbon oils in carboic and cresylic acids* may be estimated by mixing 100 ccm. with excess of  $20^\circ\text{Tw.}$   $\text{NaOH}$  solution and extracting with ether or light petroleum spirit. The extract is washed with a fresh portion of  $\text{NaOH}$  solution and then the separated ether is evaporated off at a low temperature and the residual oil weighed.

*Percentage of phenol and cresol in carbolic and cresylic acid.* Fox and Barker describe a method (*J.S.C.I.*, 1917 842-845, and 1918, 265-272), depending on the fact that mixtures of phenol and orthocresol containing over 80% of phenol have a simple freezing point curve. The mixture of tar acids is freed from hydrocarbon oils by solution in caustic soda, extraction with ether or benzol, liberation of the tar acids by addition of  $H_2SO_4$ , and the dehydration of the separated acids over  $CaCl_2$ . The dry acids are then distilled, using a four bulb Young's column, and the fraction to  $210^\circ C$ . collected. This is redistilled in the same apparatus and the phenol is determined in the fraction collected up to  $195^\circ C$ . by determining the freezing point and reference to a curve constructed from the following data. If the fraction contains less than 80% phenol a quantity of pure phenol is added to the distillate and allowed for after taking the freezing point.

### FREEZING POINTS.

Mixture of phenol and orthocresol.

|                                 |              |              |              |              |              |
|---------------------------------|--------------|--------------|--------------|--------------|--------------|
| % phenol in mixture             | 100          | 95           | 90           | 85           | 80           |
| Freezing point $^\circ C$ . ... | $40^\circ.2$ | $37^\circ.6$ | $34^\circ.9$ | $32^\circ.2$ | $29^\circ.3$ |

Methods are also given by Weiss and Downs (*J. Ind. Eng. Chem.*, 1917, 569-580, abstracted *J.S.C.I.*, 1917, 863), Knight, Lincoln and others (*J. Ind. Eng. Chem.*, 1918, 9-18, abstracted *J.S.C.I.*, 1918, 85 A.); Skirrow (*J. Ind. Eng. Chem.*, 1917, 1102-1106, abstracted *J.S.C.I.*, 1918, 51 A.); Dawson and Mountford (*Chem. Soc. Trans.*, 1918, **113**, 923-944), and Petrie (*J.S.C.I.*, 1919, 132-133 T.).

*Meta-cresol* is estimated by Raschig's method (see Lunge, *Coal Tar and Ammonia*, 5th edit., p. 803).

**CREOSOTE OIL** is tested for sp. gr., distilling range, percentage of water, tar acids, naphthalene and the temperature at which it is completely liquid is determined.

100 ccm. are distilled from an 8 oz. retort with the bulb of the thermometer  $\frac{3}{8}$  in. from the bottom at about two drops per second, noting the percentage of water and the quantity at  $315^\circ C$ . The tar acids are estimated in either the distillate or the original oil (if the latter is not too dirty) by extraction with  $20^\circ Tw$ . NaOH solution. The decrease in the volume of the oil is equal to the quantity of tar acids extracted, or the solution of the latter in the NaOH may be separated, decomposed with dilute acid and the liberated tar acids measured. The percentage of naphthalene is estimated by cooling a known volume or weight of creosote to an agreed

stipulated temperature and keeping the sample at this temperature for an agreed stipulated period. The deposited naphthalene is then rapidly filtered through a Buchner filter and the naphthalene is wrapped in filter paper and squeezed dry in a screw press and weighed. The percentage of naphthalene may also be estimated by Mann's "latent heat point method" (*J.S.C.I.*, 1910, p. 732). The temperature at which the creosote is completely liquid is determined by heating a few ccm. in a test tube till all is liquid, and slowly cooling whilst stirring with a thermometer, the point at which crystals first begin to form being recorded.

Sometimes the per cent. of material insoluble in benzol has to be estimated. This is done by diluting a known quantity of creosote with benzol, filtering off any insoluble matter and washing, drying and weighing in the ordinary way.

Creosote oil for fuel purposes is also tested for its flash point and burning point, its sulphur content and its calorific value. See section on Fuels and Illuminants.

CREOSOTE SALTS AND NAPHTHALENE are generally tested for liquefying point, water, impurities insoluble in benzol and sometimes for distillation point.

The liquefying point is taken by melting, say, 100—200 grammes of the sample in a small enamelled saucepan and heating up to 120°C. to ensure the elimination of water, and then cooling slowly, stirring with a thermometer. When solidification sets in the mercury will rise slightly and remain steady for some little time, and the highest point of this after-rise is the temperature of liquefaction. Water is estimated by distilling about 200 grammes from a retort until water ceases to come over. The distillate is collected in a graduated cylinder containing a few ccm. of naphtha to dissolve the naphthalene which comes over with the water. Separation of the water and naphtha may be facilitated by the addition of about 10% pure NaCl to the water.

### PITCH.

*Twisting point.* A rod of pitch  $\frac{1}{2}$  in. square and  $1\frac{1}{2}$  to 2 ins. long, moulded or cut from the sample, is suspended by a string in a beaker of water. A thermometer is also suspended so that the bulb is close to and level with the sample. The water is heated so that the temperature is raised at the rate of 1°C. per minute, and the rod is taken out at intervals and twisted round by hand. The temperature at which it can be twisted round once or twice without breaking is taken as the twisting point.

*Volatile matter.* 1 gramme of the powdered sample is

heated in a platinum crucible, with the cover on, over a bunsen burner with a flame 7in. long for 3 minutes; the crucible and contents is then heated over the blowpipe for 3 minutes longer, and weighed after cooling in the desiccator. The loss in weight represents the volatile matter.

Ash is determined either in the coke left from the volatile matter or in a fresh portion of the sample by roasting in a dish until all carbonaceous matter has been burned away.

Free carbon is estimated similarly to the free carbon in crude tar.

Considerable information as to the nature of pitch may be obtained from a study of the action of solvents, see Mansbridge (*J.S.C.I.*, 1918, 182 T.).

*General notes and precautions.* When comparing distilling points of various samples care must be taken that the conditions of the tests are the same in each case. The best way of comparing the boiling range of two samples of similar substances is to plot out a boiling point curve for each.

#### REFERENCES.

Lunge. *Coal Tar and Ammonia*.

Lunge. *Technical Methods of Chemical Analysis*, vol. iii.

Warnes. *Coal Tar Distillation*.

Spielmann. *Some Constituents of Coal Tar and their Properties*.

J. M. Weiss, S. R. Church and others. *Methods of Analysis of the Coal Tar Industry*. Pub. by the Barrett Company, New York.

Allen's *Commercial Organic Analysis*.

A good deal of work has been published during the last four or five years in the *Journal of Industrial and Engineering Chemistry* and in the *Journal of the Society of Chemical Industry*, and reference to recent volumes of these journals will well repay the trouble.

## INTERMEDIATE PRODUCTS.

### Pure Benzene and Pure Toluene.

95 per cent. of a commercially pure sample should distil within  $0.8^{\circ}\text{C}$ . Conc.  $\text{H}_2\text{SO}_4$  should give at the most a pale yellow colour.

### *Detection of Thiophen.*

A crystal of isatin is added to a small amount of concentrated sulphuric acid, and then a few drops of the sample added. The production of an intense blue colour indicates the presence of thiophen.

### *Detection of Carbon Disulphide.*

Four or five drops of phenylhydrazine are added to 10 cc. of the sample, the mixture shaken and allowed to stand for an hour. Crystals are obtained in presence of even 0.03 per cent. of carbon disulphide.

### *Detection of Phenol.*

After warming with Methyl violet, the filtrate should be absolutely colourless.

### Naphthalene.

Chemically pure samples should solidify at  $79.6-79.8^{\circ}\text{C}$ ., boil at  $217-218^{\circ}\text{C}$ ., and should give a colourless clear solution in light petroleum. The sample should not become yellow on exposure to air; this is ascertained by exposure to pure, concentrated nitric acid in a bell-jar, when the sample should remain colourless for two hours. Phenols may be detected by extracting with caustic soda, acidifying the extract with hydrochloric acid, and adding bromine water, when tribromophenols are produced.

Naphthalene can be quantitatively determined as picrate in absence of certain other hydrocarbons (Küster).

### Anthracene.

Luck's method ("Höchst test") for the valuation of anthracene is as follows:

1 gram. of the sample is weighed into a 500 cc. flask, 45 cc. of pure glacial acetic acid added, the flask connected to a reflux condenser 75 cm. long, and the contents raised to the boiling point. A freshly prepared solution of 15 gram. of chromic acid crystals in 10 cc. of pure glacial acetic acid and 10 cc. of water is added drop by drop over a period of 2 hours. After boiling for a further 2 hours, the liquid is allowed to stand for 12 hours, and 400 cc. of water are added. After standing for a further period of 3 hours the precipitate is filtered off, washed with cold, distilled water,



then with slightly alkaline, boiling water until the filtrate remains clear on acidifying, and finally with pure boiling water until the filtrate is neutral. The crude anthraquinone is rinsed into a porcelain dish, and dried at 100°C. 10 grm. of slightly fuming sulphuric acid are added, the dish heated in an air-oven at 112°C. for ten minutes and then allowed to stand in a damp place for 12 hours to absorb water. The liquid is then rinsed into a large evaporating basin by means of 200 cc. of water, the mixture allowed to cool, and the pure anthraquinone filtered off, washed and dried as above.

### Equivalent weights of Anthraquinone and Anthracene.

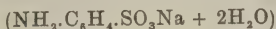
| Anthra-quinone. | Anthra-cene. | Anthra-quinone. | Anthra-cene. | Anthra-quinone. | Anthra-cene. | Anthra-quinone. | Anthra-cene. |
|-----------------|--------------|-----------------|--------------|-----------------|--------------|-----------------|--------------|
| 1               | 0.86         | 26              | 22.26        | 51              | 43.66        | 76              | 65.06        |
| 2               | 1.71         | 27              | 23.11        | 52              | 44.51        | 77              | 65.91        |
| 3               | 2.57         | 28              | 23.97        | 53              | 45.37        | 78              | 66.77        |
| 4               | 3.42         | 29              | 24.82        | 54              | 46.22        | 79              | 67.62        |
| 5               | 4.28         | 30              | 25.68        | 55              | 47.08        | 80              | 68.48        |
| 6               | 5.14         | 31              | 26.54        | 56              | 47.94        | 81              | 69.34        |
| 7               | 5.99         | 32              | 27.39        | 57              | 48.79        | 82              | 70.19        |
| 8               | 6.85         | 33              | 28.25        | 58              | 49.65        | 83              | 71.05        |
| 9               | 7.70         | 34              | 29.10        | 59              | 50.50        | 84              | 71.90        |
| 10              | 8.56         | 35              | 29.96        | 60              | 51.36        | 85              | 72.76        |
| 11              | 9.42         | 36              | 30.82        | 61              | 52.22        | 86              | 73.62        |
| 12              | 10.27        | 37              | 31.67        | 62              | 53.07        | 87              | 74.47        |
| 13              | 11.13        | 38              | 32.53        | 63              | 53.93        | 88              | 75.33        |
| 14              | 11.98        | 39              | 33.38        | 64              | 54.78        | 89              | 76.18        |
| 15              | 12.84        | 40              | 34.24        | 65              | 55.64        | 90              | 77.03        |
| 16              | 13.70        | 41              | 35.10        | 66              | 56.50        | 91              | 77.89        |
| 17              | 14.55        | 42              | 35.95        | 67              | 57.35        | 92              | 78.74        |
| 18              | 15.41        | 43              | 36.81        | 68              | 58.21        | 93              | 79.60        |
| 19              | 16.26        | 44              | 37.66        | 69              | 59.06        | 94              | 80.45        |
| 20              | 17.12        | 45              | 38.52        | 70              | 59.92        | 95              | 81.31        |
| 21              | 17.98        | 46              | 39.38        | 71              | 60.78        | 96              | 82.17        |
| 22              | 18.83        | 47              | 40.23        | 72              | 61.63        | 97              | 83.02        |
| 23              | 19.69        | 48              | 41.09        | 73              | 62.49        | 98              | 83.88        |
| 24              | 20.54        | 49              | 41.94        | 74              | 63.34        | 99              | 84.73        |
| 25              | 21.40        | 50              | 42.80        | 75              | 64.28        | 100             | 85.59        |



## Aniline.

- "Aniline oil for red," B.P. 181—183°C.,  
 Sp. Gr. 1·0265—1·0267 at 15°C.  
 "Aniline oil for blue," B.P. 182—198°C.,  
 Sp. Gr. 1·006—1·1009 at 15°C.

Aniline and other primary amines are determined as follows :  
 A standard solution of sodium sulphanilate



containing about 15 grm. per litre is prepared. 50 cc. are diluted to about 250 cc. with water, 10 cc. of hydrochloric acid added and a solution of sodium nitrite containing about 25 grm. per litre is added until a drop of the solution immediately turns cadmium iodide starch paper blue. The standardised sodium nitrite solution is used for titrating the acidified aniline cooled with ice.

## SOLUBILITY OF ANILINE (Alexeeff).

| °C. | 100 grm. water dissolve<br>grm. aniline. | °C. | 100 grm. aniline dissolve<br>grm. water. |
|-----|--|-----|--|
| 16  | 3.1                                      | 8   | 4.6                                      |
| 56  | 3.5                                      | 25  | 4.98                                     |
| 82  | 5.1                                      | 39  | 5.43                                     |
|     |  | 68  | 6.04                                     |

## Dimethylaniline.

Aniline is detected as sulphate by addition of dilute sulphuric acid.

Methylaniline is detected by allowing 10 cc. of the sample, contained in a wide test-tube, and 3 cc. of acetic anhydride, contained in a narrower test-tube, to stand in a beaker of water for some time, noting the temperature of the samples, and then observing the maximum temperature attained on rapidly adding the acetic anhydride with stirring. Each 1°C. rise in temperature corresponds to 0·5 per cent. of methylaniline. (A correction is necessary, as the temperature of pure dimethylaniline is lowered 1°C. by this treatment.)

Specific Gravity of Mixtures of *o*- and *p*-Toluidine.

| Sp. Gr. at 15°C.<br>(water at 15°C.=1) <i>o</i> -Toluidine. | %    | Sp. Gr. at 15°C.<br>(water at 15°C.=1) <i>o</i> -Toluidine. | %    |
|---|------|---|------|
| 1.0037  | 100  | 1.0004  | 72.5 |
| 36  | 99   | 03  | 72   |
| 35  | 98   | 02  | 71   |
| 34  | 97   | 01  | 70   |
| 33  | 96   | 00  | 69   |
| 32  | 95   | 0.9999  | 68.5 |
| 31  | 94   | 98  | 68   |
| 30  | 93.5 | 97  | 67   |
| 29  | 92.5 | 96  | 66.5 |
| 28  | 91.5 | 95  | 65.5 |
| 27  | 91   | 94  | 65   |
| 26  | 90   | 93  | 64   |
| 25  | 89.5 | 92  | 63   |
| 24  | 88.5 | 91  | 62   |
| 23  | 88   | 90  | 61.5 |
| 22  | 87   | 89  | 61   |
| 21  | 86.5 | 88  | 60   |
| 20  | 86   | 87  | 59   |
| 19  | 85   | 86  | 58.5 |
| 18  | 84.5 | 85  | 58   |
| 17  | 83.5 | 84  | 57.5 |
| 16  | 82.5 | 83  | 56.5 |
| 15  | 82   | 82  | 56   |
| 14  | 81   | 81  | 55   |
| 13  | 80   | 80  | 54.5 |
| 12  | 79.5 | 79  | 54   |
| 11  | 78.5 | 78  | 53   |
| 10  | 77.5 | 77  | 52.5 |
| 09  | 77   | 76  | 51.5 |
| 08  | 76   | 75  | 51   |
| 07  | 75   | 74  | 50   |
| 06  | 74   |   |      |
| 05  | 73   |   |      |

| Sp. Gr. at 20°C.<br>(water at 15°C.=1) o-Toluidine. | %    | Sp. Gr. at 20°C.<br>(water at 15°C.=1) o-Toluidine. | %    |
|---|------|---|------|
| 0.9939  | 50   | 0.9932  | 45   |
| 38  | 49.5 | 31  | 44.5 |
| 37  | 48.5 | 30  | 44   |
| 36  | 48   | 29  | 43   |
| 35  | 47.5 | 28  | 42   |
| 34  | 46.5 | 27  | 41   |
| 33  | 46   | 26  | 40   |

## Commercial Names of Intermediate Products.

(See "Notation of Organic Compounds.")

*Anthranilic acid.* o-Aminobenzoic acid.

*Ketone base.* Tetramethyldiaminobenzophenone.

*Leucotrope.* Dimethylaniline and benzyl chloride condensed to quaternary ammonium chloride.

*Naphthol AS.* Anilide of  $\beta$ -hydroxynaphthoic acid.

*Nitroso base.* p-Nitrosodimethylaniline.

*Rongalite.* Formaldehyde sodium sulphonylate,  
 $\text{CH}_2(\text{OH}).\text{OSONa}.2\text{H}_2\text{O}.$

### Dihydroxyanthraquinones.

|                                  |        |                        |
|----------------------------------|--------|------------------------|
| <i>Alizarin,</i>                 | 1 : 2- | dihydroxyanthraquinone |
| <i>Purpuroxanthin,</i>           | 1 : 3- | " "                    |
| <i>Quinizarin,</i>               | 1 : 4- | " "                    |
| <i>Anthrarufin,</i>              | 1 : 5- | " "                    |
| <i>m-Dihydroxyanthraquinone,</i> | 1 : 7- | " "                    |
| <i>Chrysazin,</i>                | 1 : 8- | " "                    |
| <i>Histazarin,</i>               | 2 : 3- | " "                    |
| <i>Anthraflavic acid,</i>        | 2 : 6- | " "                    |
| <i>Isoanthraflavic acid,</i>     | 2 : 7- | " "                    |

### Trihydroxyanthraquinones.

|                        |            |                         |
|------------------------|------------|-------------------------|
| <i>Anthraqallol,</i>   | 1 : 2 : 3- | trihydroxyanthraquinone |
| <i>Purpurin,</i>       | 1 : 2 : 4- | " "                     |
| <i>Oxyanthrarufin,</i> | 1 : 2 : 5- | " "                     |
| <i>Flavopurpurin,</i>  | 1 : 2 : 6- | " "                     |
| <i>Isopurpurin</i>     | 1 : 2 : 7- | " "                     |
| <i>Oxychrysazin,</i>   | 1 : 2 : 8- | " "                     |

# Sulphonic Acids

- γ-Acid.* 2 : 8-Aminonaphthol-6-sulphonic acid.  
*δ-Acid.* 2-Naphthol-3-7-disulphonic acid.  
*ε-Acid.* 1-Naphthol-3 : 8-disulphonic acid.  
*Amino G salt.* 2-Naphthylamine-6 : 8-disulphonic acid, sodium salt.  
*Amino R salt.* 2-Naphthylamine-3 : 6-disulphonic acid, sodium salt.  
 Aminonaphthol disulphonic acid B (1 : 8 : 3 : 5).  
 Aminonaphthol disulphonic acid 2S (1 : 8 : 2 : 4).  
*Badische acid.* 2-Naphthylamine-8-sulphonic acid.  
*Bayer acid.* See *Crocein acid*.  
*Brönnner's acid.* 2-Naphthylamine-6-sulphonic acid.  
*Chicago acid.* See *2S acid*.  
*Chromotrope acid.* 1 : 8-Dihydroxynaphthalene-3 : 6-sulphonic acid.  
*Cleve's acids.* 1 : 6-and 1 : 7-Naphthylamine monosulphonic acids.  
*Crocein acid.* 2-Naphthol-8-sulphonic acid.  
*Dahl's acid II.* 1-Naphthylamine-4 : 6-disulphonic acid.  
*Dahl's acid III.* 1-Naphthylamine-4 : 7-disulphonic acid.  
 Dihydroxynaphthalene sulphonic acid S (1 : 8 : 4).  
 Dihydroxynaphthalene disulphonic acid K (1 : 8 : 4 : 6).  
*Eikonogen.* 1 : 2-Aminonaphthol-6-sulphonic acid ; sodium salt.  
*F acid.* 2-Naphthol-7-sulphonic acid.  
*G acid.* 2-Naphthol-6 : 8-disulphonic acid.  
*H acid.* 1 : 8-Aminonaphthol-3 : 6-disulphonic acid.  
*J acid.* 2 ; 5-Aminonaphthol-7-sulphonic acid.  
*K acid.* 1 : 8-Aminonaphthol-4 : 6-disulphonic acid.  
*L (Laurent's) acid.* 1-Naphthylamine-5-sulphonic acid.  
*Metanilic acid.* Aniline-*m*-sulphonic acid.  
*Naphthionic acid.* 1-Naphthylamine-4-sulphonic acid.  
*ortho-Naphthionic acid.* 1-Naphthylamine-2-sulphonic acid.  
*α-Naphthol sulphonic acid C* (1 : 5).  
 Naphthylamine disulphonic acid Sch. (1 : 4 : 8).  
*Nigrotic acid.* Dihydroxysulphonaphthoic acid (2 : 8 : 3 : 6).  
*N.W. (Nevile and Winther's) acid.* 1-Naphthol-4-sulphonic acid.  
*Peri-acid.* 1-Naphthylamine-8-sulphonic acid.  
*Phenyl Peri-acid.* 1-Phenylnaphthylamine-8-sulphonic acid.  
*R acid.* 2-Naphthol-3 : 6-disulphonic acid.  
*2R acid.* 2 : 8-Aminonaphthol-3 : 6-disulphonic acid.  
*S acid.* 1 : 8-Aminonaphthol-4-sulphonic acid.  
*2S acid.* 1 : 8-Dihydroxynaphthalene-2 : 4-disulphonic acid.  
*Schäffer's acid.* 2-Naphthol-6-sulphonic acid.  
*Schöllkopfs acid.* 1-Naphthol-4 : 8-disulphonic acid.  
*Sulphanilic acid.* Aniline-*p*-sulphonic acid.  
*Tolyl Peri-acid.* 1-Tolyl-naphthylamine-8-sulphonic acid,

## Formation of Azo-compounds.

### Rules for Coupling with Diazo-compounds.

#### *With Benzene Derivatives:*

Coupling occurs in *para*-position to the OH or  $\text{NH}_2$  group, if free; otherwise in *ortho*-position, if free. If both *ortho*- and *para*-positions are occupied, coupling does not take place. (Exceptions to this rule are known).

#### *With $\alpha$ -Derivatives of Naphthalene:*

Coupling occurs in *para*- ( $\alpha$ ) position to the OH or  $\text{NH}_2$  group provided that this position and the adjacent  $\beta$ -position are *both* free; otherwise in *ortho*-( $\beta$ ) position, if free. In case this last-named position is occupied, coupling does not take place.

#### *With $\beta$ -Derivatives of Naphthalene:*

Coupling occurs in  $\alpha$ -position adjacent to the OH or  $\text{NH}_2$  group if free, and in no other position.

---

# The Composition of Synthetic Dyestuffs

## With Some Notes on their Preparation.

*Acetine blue.* Soln. of Induline in acetine.

*Acid Alizarin black R.* Nitro *o*-aminophenol sulphonic acid diazotised +  $\beta$ -naphthol.

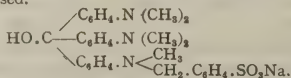
*Acid Alizarin blue BB, GR.* Sulphonic acids of *Anthracene blue WR.*

*Acid blue 6G.* See *Cyanol.*

*Acid green.* See *Light green SF.*

*Acid Magenta.* Sulphonated Magenta; ammonium salt.

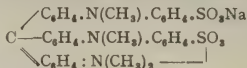
*Acid violet 4BN.* Ketone base condensed with benzylmethylaniline; sulpho-  
nated; oxidised.



*Acid violet 6B.* Disulphonic acid of dimethyldiethyldibenzylpararosaniline.

*Acid violet 6BN.* Ketone base condensed with *p*-tolyl-*m*-ethoxyphenylamine  
sulphonated; oxidised.

*Acid violet 7B.* From *p*-diethylaminobenzoyl chloride and methyldiphenylamine

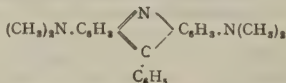


*Acid yellow GR.* See *Fast yellow G.*

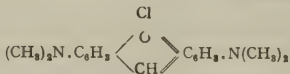
*Acid yellow C.* See *Naphthol yellow S.*

*Acid yellow D.* See *Diphenylamine orange.*

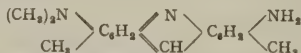
*Acridine orange R extra.* Condensation of benzaldehyde with *m*-aminodimethy-  
aniline; elimination of ammonia; oxidation.



*Acridine red B.* Oxidation of *Pyronine G* with permanganate.



*Acridine yellow.* Action of formaldehyde on *m*-toluylenediamine; oxidation  
with ferric chloride.



*Afghan yellow.* See *Curcumine S.*

*Algol blue CF.* Chloro-derivative of indanthrene.

*Algol blue 3G.* A dihydroxy-indanthrene.

*Algol blue 3R.* Dibenzoyldiaminoanthrarufin.

*Algol bordeaux 3B.* An anthraquinonemide.

*Algol Brilliant orange FR.* Benzoyl-1 : 2 : 4-triaminoanthraquinone.

*Algol Brilliant red 2B.* 1 : 5-Dibenzoyldiamino-4-hydroxy-anthraquinone.

*Algol Brilliant violet 2B.* See *Algol blue 3R.*

*Algol green B.* Dibromo-diamino-indanthrene.

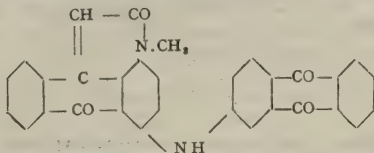
**Algol grey B.** Nitration of trianthramide obtained by condensing 1 : 5-diamino anthraquinone with two molecules of  $\alpha$ -chloro-anthraquinone and reduction of the product with an alkali sulphide.

**Algol olive R.** Action of chlorosulphonic acid on dibenzoyldiamino-anthraquinone.

**Algol orange R.** An anthraquinoneimide.

**Algol pink R.** Benzoyl-4-amino-1-hydroxy-anthraquinone.

**Algol red B.**



**Algol red 5G.** Dibenzoyl-1 : 4-diamino-anthraquinone.

**Algol red R extra.** Dibenzoyl-1 : 5-diamino-8-hydroxy-anthraquinone.

**Algol scarlet G.** Benzoyl-1-amino-4-methoxy-anthraquinone.

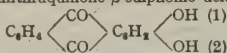
**Algol violet B.** Benzoyl-amino-4 : 5 : 8-trihydroxy-anthraquinone.

**Algol yellow 3G.** Succinyl-(1-amino-anthraquinone)<sub>2</sub>.

**Algol yellow R.** Dibenzoyl-1 : 5-diamino-anthraquinone.

**Algol yellow WG.** Benzoyl-1-amino-anthraquinone.

**Alizarin.** Fusion of anthraquinone- $\beta$ -sulphonic acid with caustic alkalis.

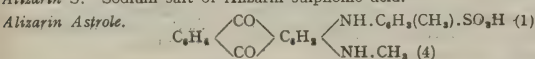


**Alizarin OG and OR.** See *Alizarin orange*.

**Alizarin GI, RG, SDG, X.** See *Flavopurpurin*.

**Alizarin SX, GD.** See *Anthrapurpurin*.

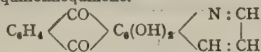
**Alizarin S.** Sodium salt of Alizarin sulphonic acid.



**Alizarin blacks.** 1 : 2-Dihydroxynaphthaquinone (Naphthazarin) + NaHSO<sub>3</sub>.

**Alizarin blue.**  $\beta$ -Nitroalizarin heated with glycerin and sulphuric acid.

Dihydroxyanthraquinolinequinone.



**Alizarin blue S.** Sodium bisulphite compound of *Alizarin blue*.

**Alizarin blue-green.** Sulphonic acid of a trihydroxyanthraquinolincquinone.

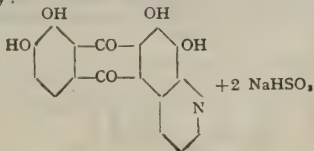
**Alizarin bordeaux.** 1 : 2 : 5 : 8-Tetrahydroxyanthraquinone.

**Alizarin Celestole.** Action of formaldehyde on *Alizarin Saphirole B*.

**Alizarin Cyanine.** 1 : 2 : 4 : 5 : 8-pentahydroxyanthraquinone.

**Alizarin Cyanine green E, G, K.** Sulphonation of 1 : 4 di-*p*-toluidino anthraquinone.

**Alizarin indigo blue S, SW.** Action of sulphuric acid at 200° C. on Alizarin green. Mainly :







**Aniline blue** (spirit-soluble). Mixture of triphenylpararosaniline and diphenylrosaniline hydrochlorides.

**Aniline brown.** See *Bismarck brown*.

**Aniline pink.** See *Safranin*.

**Aniline purple.** See *Mauveine*.

**Aniline red.** See *Magenta*.

**Aniline violets.** Alkylated Rosanilines.

**Aniline yellow.** Amidoazobenzene hydrochloride.

**Anisolines.** Esters of Rhodamines.

**Anthracene blue WR.** 1:5-Dinitroanthraquinone heated with fuming  $H_2SO_4$ , 1:3:4:5:7:8-Hexahydroxyanthraquinone.

**Anthracene blue WG.** Above dyestuff heated with caustic soda and ammonia under pressure.

**Anthracene blue WGG.** 1:5-Dinitroanthraquinone heated with fuming  $H_2SO_4$ , sulphur and boric acid.

**Anthracene brown.** See *Anthragallol*.

**Anthracene Chrome black.** Amino R salt diazotised +  $\beta$ -naphthol.

**Anthracene green.** See *Cærulein*.

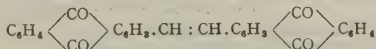
**Anthracene red.** o-Nitrobenzidine tetrazotised  $\left\{ \begin{array}{l} \text{salicylic acid.} \\ \text{N.W. acid.} \end{array} \right.$

**Anthracene violet.** See *Gallein*.

**Anthracite black.** Dahl's acid II. diazotised +  $\alpha$ -naphthylamine, diazotised + diphenyl-*m*-phenylenediamine.

**Anthracyanines.** Derived from Gallocyanines.

**Anthraflavone.** Oxidation of 2-methylantraquinone. Diphthaloylstilbene.

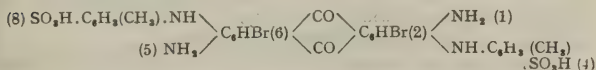


**Anthragallol.** 1:2:3-Trihydroxyanthraquinone.

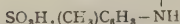
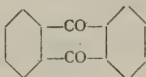
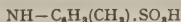
**Anthrapurpurin.** 1:2:7-Trihydroxyanthraquinone.

**Anthraquinone black.** 1:5-Dinitronaphthalene heated with polysulphide until soluble in water.

**Anthraquinone blue.** 2:4:6:8-Tetrabromo-1:5-diaminoanthraquinone heated with *p*-toluidine; sulphonation.



**Anthraquinone violet.**



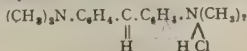
**Anthrarufin.** 1:5-Dihydroxyanthraquinone.

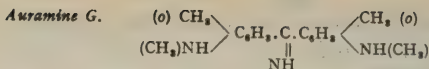
**Apollo red.** See *Orchil substitute 3VN*.

**Aposafraanine.** Diazotised Safranin boiled with alcohol.

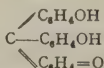
**Atlas red.** Primuline diazotised + *m*-toluylenediamine.

**Auramine.** Ammonia passed into a fused mixture of dimethyldiaminodiphenyl methane and sulphur.





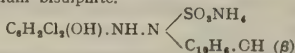
*Aurin.* Pararosaniline acid.



*Auronal black.* *p*-Aminodinitrodiphenylamine treated with alkali polysulphide.

*Azalein.* Aniline heated with mercuric nitrate. See *Magenta*.

*Azarine S.* Aminodichlorophenol diazotised +  $\beta$ -naphthol; product treated with ammonium bisulphite.



*Azidine Fast scarlets.* Derivatives of the complex urea obtained by passing carbonyl chloride into a mixture of one molecule of *m*-toluylenediamine, 1-sulphonic acid and two molecules of J acid.

*Azo black-blue.* Tolidine tetrazotised  $\begin{cases} \text{H acid} \\ m\text{-hydroxydiphenylamine.} \end{cases}$

*Azo blue.* Tolidine tetrazotised + 2 mols. N.W. acid; sodium salt.

*Azo bordeaux.*

Tolidine tetrazotised  $\begin{cases} \text{aminophenol sulphonic acid.} \\ m\text{-phenylenediamine + diazotised naphthionic acid.} \end{cases}$

*Azo carmine.* Phenylrosinduline disulphonic acid.

*Azochromine.* Aminophenol diazotised + pyrogallol.

*Azo cochineal.* *o*-Anisidine diazotised + Schöllkopf's acid.

*Azococcine 2R.* Xylidine diazotised + N.W. acid; sodium salt.

*Azocoralline.* *p*-Aminoacetanilide diazotised + R acid.

*Azocorinth.* Naphthionic acid diazotised  $\begin{cases} \text{Resorcinol.} \\ \text{Aminophenol sulphonic acid.} \end{cases}$

*Azoeosin.* *o*-Anisidine diazotised + N.W. acid.

*Azoflavine S.* Highly nitrated Diphenylamine orange.

*Azo green.* *m*-aminotetramethyl-*p*-diaminotriphenylmethane diazotised + salicylic acid, and oxidation.

*Azo Magenta G.* Sulphanilic acid diazotised + S acid.

*Azo mauve.* Tolidine tetrazotised  $\begin{cases} \text{H acid.} \\ \alpha\text{-naphthylamine (alkaline soln).} \end{cases}$

*Azophenosafranines.* Asymmetrical Safranines.

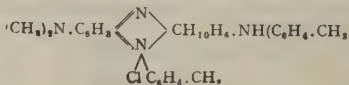
*Azophosphine G.O.* *m*-Aminophenyltrimethylammonium chloride diazotised + resorcinol.

*Azorubine S.* See *Amaranth*.

*Azo violet.* Dianisidine tetrazotised  $\begin{cases} \text{naphthionic acid} \\ \text{N.W.' acid} \end{cases}$  sodium salt.

*Azo yellow.* Nitrated Diphenylamine orange.

*Aasle blue R.* Nitrosodimethylaniline condensed with 2 : 7-ditolynaphthylendiamine.



*Bavarian blue.* See *Diphenylamine blue*.

*Benzaldehyde green.* See *Malachite green*.

*Benzo Azurine G.* Dianisidine tetrazotised + 2 mols. N.W. acid.

*Benzo black-blue G.*

Benzidine disulphonic acid tetrazotised  $\left\{ \begin{array}{l} \alpha\text{-naphthylamine, diazotised +} \\ \text{N.W. acid.} \\ \text{N.W. acid.} \end{array} \right.$

*Benzo black-blue R.*

Tolidine tetrazotised  $\left\{ \begin{array}{l} \text{N.W. acid.} \\ \alpha\text{-naphthylamine, diazotised + N.W. acid.} \end{array} \right.$

*Benzo blue BB.* Benzidine tetrazotised + 2 mols. H acid (in alkaline soln.).

*Benzo Brilliant blue.* See *Soluble blue XG*.

*Benzo brown.* Naphthionic acid diazotised + *Bismarck brown*.

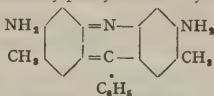
*Benzo brown G.* Sulphanilic acid  $\left\{ \begin{array}{l} \\ m\text{-phenylenediamine.} \end{array} \right.$

*m*-Phenylenediamine  $\left\{ \begin{array}{l} \\ m\text{-phenylenediamine.} \end{array} \right.$

Sulphanilic acid

*Benzo Fast scarlets.* Diazobenzene, &c. + complex urea obtained by the action of carbonyl chloride on 2 mols. J acid.

*Benzoflavine.* Diaminodimethylphenylacridine hydrochloride.



*Benzo indigo blue.*

Tolidine tetrazotised  $\left\{ \begin{array}{l} \text{dihydroxynaphthalene sulphonie acid S.} \\ \alpha\text{-naphthylamine, diazotised + dihydroxynaphthalene} \\ \text{sulphonie acid S.} \end{array} \right.$

*Benzo olive.*

Benzidine tetrazotised  $\left\{ \begin{array}{l} \text{salicylic acid.} \end{array} \right.$

*Benzo orange K.*

Benzidine tetrazotised  $\left\{ \begin{array}{l} \alpha\text{-naphthylamine, diazotised + H acid.} \\ \text{salicylic acid.} \\ \text{naphthionic acid.} \end{array} \right.$

*Benzo Pure blue.* See *Diamine Pure blue*.

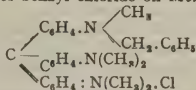
*Benzopurpurine B.* Tolidine tetrazotised + 2 mols. Brönnner's acid.

*Benzopurpurine 4B.* Tolidine tetrazotised + 2 mols. naphthionic acid.

*Benzopurpurine 6B.* Tolidine tetrazotised + 2 mols. L acid.

*Benzopurpurine 10B.* Dianisidine tetrazotised + 2 mols. naphthionic acid.

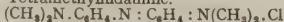
*Benzyl violet.* Action of benzyl chloride on *Methyl violet B*.



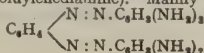
*Biebrich Patent black 4NA.* Naphthionic acid diazotised + Cleve's acids diazotised +  $\alpha$ -naphthylamine.

*Biebrich scarlet.* Aminoazobenzene disulphonic acid diazotised +  $\beta$ -naphthol.

*Bindschöller's green.* Oxidation of dimethyl-*p*-phenylenediamine and dimethyl-aniline. Tetramethylindamine.

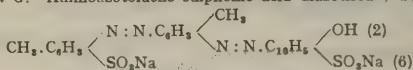


*Bismarck brown.* *m*-Phenylenediamine tetrazotised + 2 mols. *m*-phenylenediamine (or *m*-toluylenediamine). Mainly



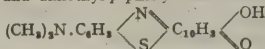
*Bordeaux B.*  $\alpha$ -Naphthylamine diazotised + R acid.

*Bordeaux G.* Aminoazotoluene sulphonic acid diazotised + Schäffer's acid.



*Bordeaux S.* Naphthionic acid diazotised + R acid.

*Brilliant Alizarin blue G, R.*  $\beta$ -Naphthoquinone- $\alpha$ -sulphonic acid or -2 : 5-disulphonic acid and dimethyl-*p*-phenylenediamine thiosulphonic acid.



*Brilliant Azurine 5G.* Dianisidine diazotised + 2 mols. dihydroxynaphthalene. sulphonic acid S.

*Brilliant Congo G.* Benzidine tetrazotised + amino R salt, diazotised + Brönner's acid.

*Brilliant Congo R.* Tolidine tetrazotised + amino R salt, diazotised + Brönner's acid.

*Brilliant Congo 2R.* Tolidine tetrazotised  $\begin{cases} \text{amino R salt.} \\ \text{F acid.} \end{cases}$

*Brilliant Cotton blue.* See *Helvetia blue*.

*Brilliant Crocein.* Aminoazobenzene diazotised + G acid.

*Brilliant green.* Tetraethyldiaminofuchsonimonium sulphate, or  $\text{ZnCl}_2$  double salt.

*Brilliant orange G.* Aniline diazotised + Schäffer's acid.

*Brilliant orange O.* Toluidine diazotised + Schäffer's acid.

*Brilliant orange R.* Xylidine diazotised + Schäffer's acid.

*Brilliant ponceau 4R.* Brönner's acid diazotised + N.W. acid.

*Brilliant ponceau 5R.* Naphthionic acid diazotised + G acid.

*Brilliant Purpurine R.* Tolidine tetrazotised  $\begin{cases} \text{amino R salt.} \\ \text{naphthionic acid.} \end{cases}$

*Buffalo Rubine.*  $\alpha$ -Naphthylamine diazotised + Schöllkopf's acid.

*Cachou de Laval.* Organic matter (sawdust, &c.) fused with sodium polysulphide.

*Capri blue.* Condensation of nitrosodimethylaniline with dimethyl-*m*-amino cresol.

*Carmoisine B.* Naphthionic and diazotised + N.W. acid.

*Carnotine.* See *Primuline*.

*Cattà Italiano.* See *Cachou de Laval*.

*Cerise.* Mixture of *Magenta* and *Phosphine*.

*Cerotine yellow R.* Aniline diazotised + resorcinol.

*Cerotine orange.* Aniline diazotised + *m*-toluylenediamine.

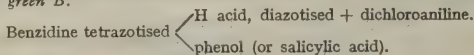
*Chicago blue B.* Dianisidine tetrazotised + 2 mols. S acid.

*Chicago blue 2B, 4B, 6B, 2R.* Mixed Disazo-dyestuffs with 1 mol. S acid and 1 mol. another compound.

*Chicago blue R.* Tolidine tetrazotised + 2 mols. S acid.

*Chicago orange.* *p*-Nitrotoluene sulphonic acid boiled with caustic soda in presence of an amino-compound.

*Chloramine green B.*

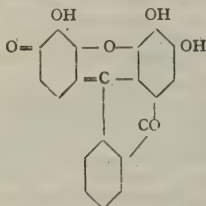


*Chloramine yellow.* Action of alkali hypochlorite on dehydrothio-*p*-toluidine sulphonic acid





- Ciba yellow G.* Brominated *Indigo yellow 3G Ciba.*  
*Cibanone black B, 2B.* 2-Methylbenzanthrone fused with sulphur.  
*Cibanone blue 3G.* As *Cibanone black.*  
*Cibanone brown.* Amino-2-methylantraquinone fused with sulphur.  
*Cibanone green B.* As *Cibanone black.*  
*Cibanone orange R.* From dichloro-methylantraquinone.  
*Cibanone yellow R.* From  $\omega$ -monochloro-methylantraquinone.  
*Citronin A.* Naphthol yellow S.  
*Citronin.* Nitrated *Diphenylamine orange.*  
*Clayton Fast black D.* Action of free thiosulphuric acid on nitrosophenol.  
*Clayton Cloth red.* Dehydrothiotoluidine sulphonic acid diazotised +  $\beta$ -naphthol  
*Clayton yellow.* See *Thiazol yellow G.*  
*Cloth red B.* Amidoazotoluene diazotised + R acid.  
*Cloth red B extra G.* Amidoazobenzene diazotised + N.W. acid.  
*Cloth scarlet G.* Amidoazobenzene monosulphonic acid diazotised +  $\beta$ -naphthol.  
*Coccin 2B.* See *Crocein 3BX.*  
*Cochineal red A.* Naphthionic acid diazotised + G acid.  
*Cochineal scarlet PS.* *m*-Xylidine diazotised + R acid (or G acid).  
*Cochineal scarlet 2R.* Toluidine diazotised +  $\alpha$ -naphthol sulphonic acid C.  
*Cochineal scarlet 4R.* *m*-Xylidine diazotised +  $\alpha$ -naphthol sulphonic acid C.  
*Cærulein.* Gallein heated with concentrated  $\text{H}_2\text{SO}_4$ .



*Cærulein S.* Bisulphite compound of *Cærulein.*

*Columbia black B.*

Dianisidine  $\left\{ \begin{array}{l} 2 \text{ R acid, diazotised} + m\text{-toluylenediamine.} \\ m\text{-toluylenediamine.} \end{array} \right.$

*Columbia black R.*

Tolidine  $\left\{ \begin{array}{l} 2 \text{ R acid, diazotised} + m\text{-toluylenediamine.} \\ m\text{-toluylenediamine.} \end{array} \right.$

*Columbia blue G.*

Tolidine tetrazotised  $\left\{ \begin{array}{l} \text{S acid.} \\ \text{another compound.} \end{array} \right.$

*Columbia blue R.*

Benzidine  $\left\{ \begin{array}{l} \text{S acid.} \\ \text{naphthol sulphonic acid.} \end{array} \right.$

*Congo blue 3B.*

Tolidine tetrazotised  $\left\{ \begin{array}{l} \text{H acid.} \\ \text{H acid (alkaline soln.).} \end{array} \right.$

*Congo blue BX.* See *Diamine blue BX.*

*Congo blue 2BX.* See *Diamine blue 2B.*

*Congo Corinth B.*

Tolidine tetrazotised  $\left\{ \begin{array}{l} \text{naphthionic acid.} \\ \text{N.W. acid.} \end{array} \right.$

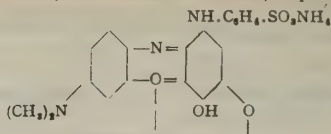
*Congo Corinth G.*

Benzidine tetrazotised  $\left\{ \begin{array}{l} \text{naphthionic acid.} \\ \text{N.W. acid.} \end{array} \right.$





*Delphine blue B.* Gallocyamine heated with aniline, sulphonated.



*Dellapurpurine.*

Benzidine tetrazotised  $\left\{ \begin{array}{l} \beta \text{ naphthylamine sulphonic acid F.} \\ \text{Brönnner's acid.} \end{array} \right.$

*Dellapurpurine 7B.* Tolidine tetrazotised + 2 mols.  $\beta$ -naphthylamine sulphonic acid F.

*Diamine black BH.*

Benzidine tetrazotised  $\left\{ \begin{array}{l} \gamma\text{-acid (alkaline soln.).} \\ \text{H acid (alkaline soln.).} \end{array} \right.$

*Diamine black 3O.* Ethoxybenzidine tetrazotised + 2 mols.  $\gamma$ -acid (alkaline soln.).

*Diamine black RO.* Benzidine tetrazotised + 2 mols.  $\gamma$ -acid (alkaline soln.).

*Diamine blue B.*

Ethoxybenzidine tetrazotised  $\left\{ \begin{array}{l} \delta\text{-acid.} \\ \text{N.W. acid.} \end{array} \right.$

*Diamine blue 2B.*

Benzidine tetrazotised  $\left\{ \begin{array}{l} \text{H acid.} \\ \text{H acid (alkaline soln.).} \end{array} \right.$

*Diamine blue 3B.*

Tolidine tetrazotised  $\left\{ \begin{array}{l} \text{H acid.} \\ \text{H acid (alkaline soln.).} \end{array} \right.$

*Diamine blue BX*

Tolidine tetrazotised  $\left\{ \begin{array}{l} \text{NW acid.} \\ \text{H acid (alkaline soln.).} \end{array} \right.$

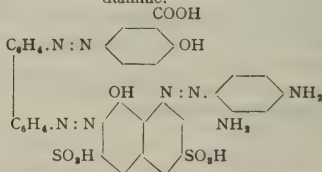
*Diamine blue 3R.* Ethoxybenzidine tetrazotised + 2 mols. N.W. acid.

*Diamine blue-black.*

Ethoxybenzidine tetrazotised  $\left\{ \begin{array}{l} \delta\text{-acid.} \\ \gamma\text{-acid (alkaline soln.).} \end{array} \right.$

*Diamine bronze G.*

Benzidine tetrazotised  $\left\{ \begin{array}{l} \text{salicylic acid.} \\ \text{H acid (alkaline soln.), diazotised + } m\text{-phenylene diamine.} \end{array} \right.$



*Diamine brown M.*

Benzidine tetrazotised  $\left\{ \begin{array}{l} \text{salicylic acid.} \\ \gamma\text{-acid (alkaline soln.).} \end{array} \right.$

*Diamine brown V.*

Benzidine tetrazotised  $\left\{ \begin{array}{l} \gamma\text{-acid (alkaline soln.).} \\ m\text{-phenylenediamine.} \end{array} \right.$

*Diamine Fast red.*

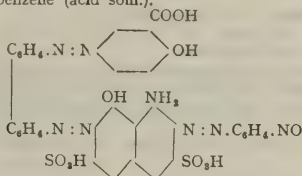
Benzidine tetrazotised  $\left\{ \begin{array}{l} \text{salicylic acid.} \\ \gamma\text{-acid (acid soln.).} \end{array} \right.$

*Diamine golden-yellow.* 1 : 5-Diaminonaphthalene-3 : 7-disulphonic acid tetrazotised + 2 mols. phenol; ethylated.

*Diamine green B.*

Benzidine tetrazotised  $\left\{ \begin{array}{l} \text{salicylic acid.} \\ \text{H acid (alkaline soln.)} \end{array} \right.$

+ diazo-*p*-nitrobenzene (acid soln.).



*Diamine red B.*

Folidine tetrazotised  $\left\{ \begin{array}{l} \beta\text{-naphthylamine sulphonic acid F.} \\ \text{Brönner acid.} \end{array} \right.$

*Diamine red 3B.* Tolidine tetrazotised + 2 mols.  $\beta$ -naphthylamine sulphonic acid F.

*Diamine scarlet.*

Benzidine tetrazotised  $\left\{ \begin{array}{l} \text{G acid} \\ \text{phenol.} \end{array} \right.$  ; ethylated.

*Diamine Sky blue.* Dianisidine tetrazotised + 2 mols. H acid.

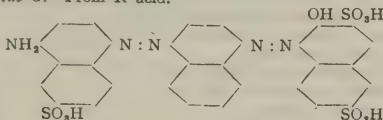
*Diamine violet N.* Benzidine tetrazotised + 2 mols.  $\gamma$ -acid (acid solution).

*Diamine yellow N.*

Ethoxybenzidine tetrazotised  $\left\{ \begin{array}{l} \text{salicylic acid} \\ \text{phenol.} \end{array} \right.$  ; ethylated.

*Diaminogen black.* 4-Acetamino- $\alpha$ -naphthylamine-6-sulphonic acid diazotised +  $\alpha$ -naphthylamine, diazotised +  $\gamma$ -acid; acetyl group saponified.

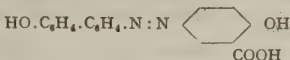
*Diaminogen blue G.* From R acid.



*Diamond black.* Aminosaliclic acid diazotised +  $\alpha$ -naphthylamine, diazotised + N.W. acid.

*Diamond black PV.* *o*-Aminophenol-*p*-sulphonic acid diazotised + 1 : 5 dihydroxynaphthalene.

*Diamond Flavine G.* Benzidine tetrazotised + 1 mol. salicylic acid, boiled.



*Diamond green.* Aminosaliclic acid diazotised +  $\alpha$ -naphthylamine, diazotised + 1 : 8-dihydroxy-naphthalene-4-sulphonic acid.

*Diamond green.* See *Malachite green*.

*Diamond Magenta.* Large crystals of *Magenta*.

*Diamond yellow G.* *m*-Aminobenzoic acid diazotised + salicylic acid.

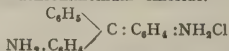
*Dianil black R.*

Naphthionic acid diazotised  $\left\{ \begin{array}{l} \text{dihydroxynaphthalene disulphonic acid.} \\ \text{---} \end{array} \right.$

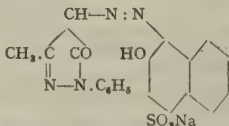
Benzidine tetrazotised  $\left\{ \begin{array}{l} \text{---} \\ \text{---} \end{array} \right.$

*m*-phenylenediamine.

- Dianil blue B.* Tolidine tetrazotised + 2 mols. chromotrope acid.  
*Dianil blue G.* Dianisidine tetrazotised + 2 mols. chromotrope acid.  
*Dianisidine blue.* Dianisidine tetrazotised + 2 mols.  $\beta$ -naphthol: copper salt on the fibre.  
*Dianthine.* Di-iodo-fluorescein.  
*Dianthine.* See *St. Denis red*.  
*Diazo Brilliant scarlets.* Thiazol derivatives of J acid coupled with diazo-benzene, &c.  
*Dimethylaniline orange.* See *Orange III*.  
*Dioxine.* Action of  $\text{HNO}_2$  on 2:7-dihydroxynaphthalene. 7-Hydroxy- $\beta$ -naphthoquinone monoxime.  
*Diph nylamine blue.* Triphenylpararosanine hydrochloride.  
*Diphenylamine orange.* Sulphanilic acid diazotised + diphenylamine.  
*Diphenyl Fast yellow.* Dinitrodibenzyl disulphonic acid condensed with *Primuline*.  
*Direct brown J.* 2 Mols. *m*-aminobenzoic acid diazotised + 1 mol. *Bismarck brown*.  
*Direct Sky blue.* See *Diamine Sky blue*.  
*Direct yellow G.* *p*-Nitrotoluene sulphonic acid treated with conc. NaOH.  
*Direct yellow RT.* See *Curcumin S*.  
*Döbner's violet.* Amidofuchsonimonium chloride.

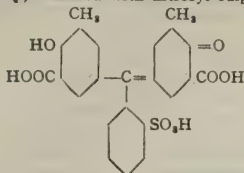


- Double Brilliant scarlet G.* Brönner acid diazotised +  $\beta$ -naphthol.  
*Double scarlet S.* See *Brilliant ponceau 4R*.  
*Eclipse browns.* Mixtures of *m*-toluylenediamine with several bases and acids, such as oxal-*m*-toluylenediamine, nitrotoluidines, phthalic acid, thio-diglycollic acid, &c., heated with polysulphide.  
*Eclipse brown B.* *m*-Toluylenediamine and oxalic acid heated with polysulphide.  
*Eclipse red.* Sulphurisation of Aziaes.  
*Eclipse yellow G, 3G.* Fusion of mono- or di-formyl-*m*-toluylenediamine (alone or mixed with benzidine) with sulphur at  $240^\circ \text{C}$ .  
*Eosin A (yellow).* Tetrabromo-fluorescein; sodium salt.  
*Eosin (bluish).* See *Erythrosin*.  
*Eosin BN.* Dibromodinitro-fluorescein; alkali salt.  
*Eosin 10B.* Tetrachlorotetrabromo-fluorescein.  
*Eosin S.* Ethyl ester of *Eosin*.  
*Eosin scarlet.* See *Eosin BN*.  
*Erica B.* Dehydrothio-*m*-xylylidine diazotised +  $\epsilon$ -acid.  
*Eriochlorine.* Allied to *Erioglaucine*.  
*Eriochrome blue-black. B, R.* 1-Amino-2-naphthol-4-sulphonic acid diazotised +  $\alpha$  or  $\beta$  naphthol.  
*Eriochrome red B.* 1-Amino-2-naphthol-4-sulphonic acid diazotised + 1-phenyl-3-methyl-5-pyrazolone.



- Erio Cr. me Azurole B.* *o*-Chlorobenzaldehyde and *o*-cresotinic acid condensed by  $\text{H}_2\text{SO}_4$ ; oxidised with nitrosyl sulphate.

**Erio Chrome Cyanine.** Benzaldehyde-*o*-sulphonic acid and *o*-cresotinic acid condensed by  $\text{H}_2\text{SO}_4$ ; oxidised with nitrosyl sulphate.



**Eriocyanine.** Tetramethyldiaminobenzhydrol condensed with dibenzylaniline sulphonic acid; oxidation. Sodium salt.

**Erioglaurine A.** Benzaldehyde *o*-sulphonic acid condensed with ethylbenzylaniline sulphonic acid; oxidation. Ammonium salt.

**Erythrines.** Esters of *Eosin*.

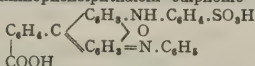
**Erythrosin B.** Tetraiodo-fluorescein.

**Ethyl green.** See *Brilliant green*.

**Ethyl violet.** Hexaethylpararosaniline hydrochloride.

**Fast Acid violet B.** Fluorescein chloride and aniline condensed; sulphonated.

Diphenyl-*m*-aminophenolphthalein sulphonic acid.



**Fast Benzo orange S.** Derivative of complex<sup>7</sup>urea obtained by treating J acid with phosgene gas.

**Fast black B.** 1:8-Dinitronaphthalene treated with sodium sulphide in aqueous soln.

**Fast blue.** See *New blue R*.

**Fast blue B.** (spirit-soluble). Induline obtained by heating amidoazobenzene with aniline and aniline hydrochloride.

**Fast blue B.** Sulphonic acid of above.

**Fast blue R** (spirit-soluble). Induline obtained by heating nitrophenol with aniline and aniline hydrochloride.

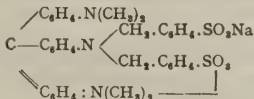
**Fast blue R.** Sulphonic acid of above.

**Fast brown.** 2 Mols. naphthionic acid diazotised + 1 mol. resorcinol.

**Fast browns.** Monoazo- and Disazo-dyestuffs from  $\alpha$ - or  $\beta$ -naphthylamine sulphonic acids +  $\alpha$ -naphthol.

**Fast green.** See *Alsace green*.

**Fast green extra.** Tetramethyldibenzyl-pararosaniline disulphonic acid.



**Fast Marine blue.** See *New blue R*.

**Fast ponceau B.** See *Biebrich scarlet*.

**Fast red.** Naphthionic acid diazotised + Schaffer's acid.

**Fast red A.** Naphthionic acid (or L acid) diazotised +  $\beta$ -naphthol.

**Fast red B.**  $\alpha$ -Naphthylamine diazotised + R acid.

**Fast red BT.**  $\alpha$ -Naphthylamine diazotised + Schaffer's acid.

**Fast red C.** Naphthionic acid diazotised + N.W. acid.

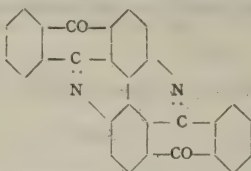
**Fast red D.** Naphthionic acid diazotised + R acid.

**Fast scarlet.** Aminoazobenzene sulphonic acid diazotised + Schaffer's acid.

**Fast yellow G.** Aminoazobenzene disulphonic acid; sodium salt.

**Fast yellow R.** Aminoazotoluene disulphonic acid; sodium salt.

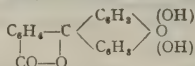
**Flavanthrene.** Alkaline fusion of  $\beta$ -aminoanthraquinone at a high temperature.



**Flavazines.** Allied to *Tartrazine*.

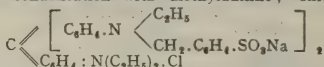
**Flavopurpurin.** 1:2:6-Trihydroxyanthraquinone.

**Fluorescein.** Phthalic anhydride condensed with 2 mols. resorcinol.



**Fluorescent blue.** Tetrabromo derivative of Resorufine.

**Formyl violet.** Formaldehyde condensed with ethylbenzylaniline sulphonic acid; oxidation; condensation with diethylaniline; oxidation.



**Fuchsia.** See *Methylene violet*.

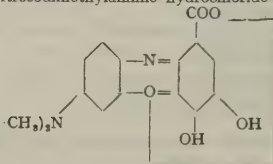
**Fuchsine (Fuchsiastine).** See *Magenta*.

**Gallamine blue.** Nitrosodimethylaniline condensed with gallamide.

**Gallanil blue.** *Gallamine blue* heated with aniline.

**Gallein.** Phthalic anhydride condensed with pyrogallol. Pyrogallol phthalein or dihydroxy-fluorescein.

**Gallocyanine.** Nitrosodimethylaniline hydrochloride condensed with gallic acid.



**Galloflavine.** Oxidation of gallic acid.

**Gallo violet.** A leuco *Pyrogallocyanine*.

**Gambine B.** Action of  $HNO_2$  on 2:7-dihydroxynaphthalene.

**Gambine G, Y.** Action of  $HNO_2$  on  $\beta$ -naphthol.

**Gentian blue.** See *Aniline blue*.

**Gold brown.** See *Bismarck brown*.

**Giroflé.** Nitrosodimethylaniline condensed with xylidine.

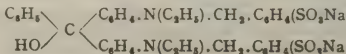
**Glacier blue.** Substituted *Malachite green*.

**Grenadine.** Impure *Magenta*.

**Grenat soluble.** Isopurpuric acid; ammonium salt.

**Grev B, R.** Induline sulphonic acids.

**Guinea green B.** Benzaldehyde condensed with ethylbenzylaniline sulphonic acid • oxidation.



**Helianshine.** Sulphanilic acid diazotised + dimethylaniline.

**Helindone blue 2B.** Mainly 5 : 5'-dibromo-indigotine.

**Helindone Fast scarlet R.** 5 : 5'-Dichloro-6 : 6'-diethoxy-thioindigo.

**Helindone grey 2B.** 7 : 7'-Diamino-thioindigo.

**Helindone grey BR.** Dichloro-7 : 7'-diamino-thioindigo.

**Helindone orange D.** Dibromo-6 : 6'-diamino-thioindigo.

**Helindone orange R.** 6 : 6'-Diethoxy-thioindigo.

**Helindone pink BN.** 6 : 6'-Dibromo-dimethyl-thioindigo.

**Helindone red B.** 5 : 5'-Dichloro-thioindigo.

**Helindone red 3B.** 5 : 5'-Dichloro-6 : 6'-dimethyl-thioindigo.

**Helindone scarlet S.** 6 : 6'-Dithioethyl-thioindigo.

**Helindone violet 2B.** Dichloro-dimethyl-dimethoxy-thioindigo.

**Helindone violet D.** Methylindoxyl condensed with isatin; bromination.

**Helindone yellow 3GN.** Urea derivative of 2 mols.  $\beta$ -aminoanthraquinone.

**Helio Fast red RL.** *m*-Nitro-*p*-toluidine diazotised +  $\beta$ -naphthol.

**Heliotrope B.** Dianisidine tetrazotised + 2 mols. ethyl  $\beta$ -naphthylamine sulphonic acid F.

**Heliotrope 2B.** Benzidine tetrazotised  $\left\{ \begin{array}{l} \text{crocein acid.} \\ \text{Schöllkopf's acid.} \end{array} \right.$

**Helvetia blue.** Condensation of formaldehyde with 2 mols. diphenylamine sulphonic acid; oxidation in presence of 1 mol. diphenylamine sulphonic acid. Trisulphonic acid of triphenylpararosaniline.

**Hessian purple N.** Diaminostilbene disulphonic acid tetrazotised + 2 mols.  $\beta$ -naphthylamine.

**Hessian yellow.** Diaminostilbene disulphonic acid tetrazotised + salicylic acid; sodium salt.

**Hofmann's violet.** Mixture of triethyl-pararosaniline and -rosaniline.

**Hydrazine yellows.** Allied to Tartrazine.

**Hydron blue B, G, R.** Sulphurisation of indophenol-carbazol or derivatives.

**Hydron blue-black.** Sulphurisation of condensation product of chlorodinitro benzene with leuco-indophenol-carbazol.

**Hydron olive G.** Sulphur chloride on anthracene (?)

**Hydron yellow G.** Dehydration product of diphthaloyl-carbazol.

**Immedial black.** 1-Chloro-2 : 4-dinitrobenzene and *p*-aminophenol fused with sodium polysulphide.

**Immedial black N.** Sulphurisation of dinitrophenol.

**Immedial black V extra.** Sulphurisation of *p*-Hydroxy-*o*'-*p*'-dinitrodiphenylamine.

**Immedial blue.** Oxidation of *Immedial black* by  $\text{H}_2\text{O}_2$ .

**Immedial blue C.** Oxidation of *Immedial black V extra* with  $\text{H}_2\text{O}_2$ . Hydroxy-dinitrodiphenylamine treated with polysulphide at a low temperature.

**Immedial bordeaux.** Azines fused with sodium polysulphide.

**Immedial bronze.** Dinitrocresol fused with polysulphide.

**Immedial brown.** Hydroxydinitrodiphenylamine treated with NaOH; fused with sodium polysulphide.

**Immedial Indone.** From Indophenol obtained by condensing *o*-toluidine and *p*-aminophenol.

**Immedial maroon.** As *Immedial bordeaux*.

**Immedial orange C, N.** *m*-Toluylenediamine fused with sulphur at 250°C.

**Immedial Pure blue.** *p*-Dimethylaminohydroxydiphenylamine treated with sulphur.

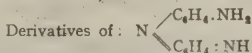
**Immedial yellow D.** *m*-Toluylenediamine fused with sulphur at 190°C.

**Immedial yellow 2G.** From dehydrothiotoluidine and benzidine.

**Imperial scarlet.** See *Biebrich scarlet*.

**Imperial violet.** Mixtures of mono- and di-phenyl and tolyl derivatives of pararosaniline and rosaniline.

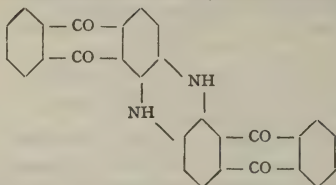
**Indamines.** Action of *p*-nitrosodimethylaniline hydrochloride on hydrochlorides of aromatic amines.



**Indanthrene X.** Fusion of  $\beta$ -aminoanthraquinone with KOH.



*Indanthrene S.* By reduction of above by warm soln. of hydrosulphite.



*Indanthrene black.* *Indanthrene green* chlorinated on the fibre.

*Indanthrene blue GC.* Dibromo-indanthrene.

*Indanthrene blue GCD.* Dichloro-indanthrene.

*Indanthrene blue 3G, 2GS.* Hydroxy-indanthrenes (?)

*Indanthrene blue RC.* Monobromo-indanthrene.

*Indanthrene blue RS.* See *Indanthrene X*.

*Indanthrene bordeaux B.* Allied to *Indanthrene red G*.

*Indanthrene dark blue BO.* Benzanthrone fused with alkali.

*Indanthrene golden orange G.* Pyranthrone by dehydration of dimethyl dianthraquinonyl.

*Indanthrene golden orange R.* Halogenation of above.

*Indanthrene green.* Nitro-derivative of *Indanthrene dark blue BO*.

*Indanthrene grey B.* Alkaline fusion of 1:5-diaminoanthraquinone.

*Indanthrene maroon.* Alkaline fusion of formaldehyde compound of 1:5 diaminoanthraquinone.

*Indanthrene olive G.* Anthracene fused with sulphur at 250°C.

*Indanthrene red G.* 1 Mol. 2:6-dichloroanthraquinone condensed with 2 mols  $\alpha$ -aminoanthraquinone.

*Indanthrene scarlet G.* Halogenation of *Indanthrene golden orange G*.

*Indanthrene violet RT.* Halogenation of *Indanthrene dark blue O*.

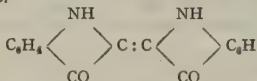
*Indanthrene yellow.* See *Flavanthrene*.

*Indazine.* Induline from nitrosodimethylaniline and diphenyl-*m*-phenylene-diamine.

*Indazurine.* Substantive dyestuff for cotton from *p*-diamines and nigrotic acid.

*Indian yellow.* Diphenylamine orange treated with dilute  $\text{HNO}_3$ .

*Indigo, Indigotine.*



*Indigo Pure B.A.S.F.* 20 per cent. paste.

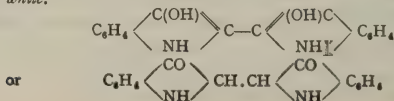
*Indigo carmine.* Indigo disulphonic acid sodium salt.

*Indigo extract.* Indigo disulphonic acid.

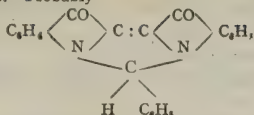
*Indigo salt.* *o*-Nitrobenzaldehyde condensed with acetone; bisulphite compound.

*Indigotine P.* Indigo tetrasulphonic acid; sodium salt.

*Indigo white.*



*Indigo yellow 3G Ciba.* Probably



*Indirubine.* Isomer of *Indigotine*.

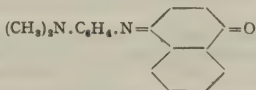


*Indocarbon S.* Indophenol-carbazol fused with sodium polysulphide in presence of copper sulphate.

*Indoine blue R.* *Safranine* diazotised +  $\beta$ -naphthol.

*Indophenine extra.* See *Induline*.

*Indophenol.* Oxidation of mixture of  $\alpha$ -naphthol and dimethyl-*p* phenylene-diamine.



*Indophenosafuranine.* Symmetrical *Safranines*.

*Indulines.* Phenylamino Mauvines.

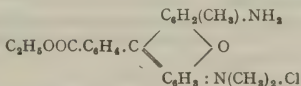
*Induline 3B.* Amidoazobenzene heated with aniline and aniline hydrochloride at 130°C.

*Induline 6B.* Above heated at 170°C.

*Ingrain colours.* *Primuline* diazotised +  $\beta$ -naphthol, &c., on the fibre.

*Iodine violet.* See *Hofmann's violet*.

*Irisamine.* Ethyl ester of dimethyl-rhodamine.



*Isamine blue.* See *Soluble blue XG*.

*Isopurpurin.* See *Anthrapurpurin*.

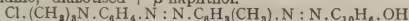
*Isorubine.* See *New Magenta*.

*Janus blue.* See *Indoine blue R*.

*Janus colours.* Amino ammonium bases  $\left( \text{Type : Aryl} \begin{array}{c} \diagup \text{NH}_2 \\ \diagdown (\text{alkyl})_3 \cdot \text{Cl} \end{array} \right)$

diazotised + phenol, &c.

*Janus red.* *m*-Aminophenyltriphenyl ammonium chloride diazotised + *m*-toluidine, diazotised +  $\beta$ -naphthol.



*Jasmine.* Nitration of *Diphenylamine orange*.

*Jet black R.* Aminobenzene disulphonic acid diazotised +  $\alpha$ -naphthylamine.

*Katigen colours.* Direct cotton Sulphur dyestuffs.

*Katigen black 2B.* From chlorodinitrophenol.

*Katigen black-brown N.* See *Cachou de Laval*.

*Katigen red-brown.* See *Eclipse red*.

*Kryogen blue, G, R.* 1 : 8-Dinitronaphthalene reduced with sodium sulphide, sodium bisulphite and NaOH; intermediate product treated with polysulphide.

*Kryogen brown.* Reduction of 1 : 8-dinitronaphthalene with sulphide or sulphite and subsequent treatment with polysulphide.

**Kryogen yellow G.** Sulphur dyestuff from thiourea derivatives of *m*-toluylene diamine mixed with benzidine.

**Kryogen yellow R.** *m*-Toluylenedithiourea fused with sulphur.

**Lacmoid.** Action of sodium nitrite on resorcinol.

**Lævuline blue.** Fast blue (*spirit-soluble*) dissolved in lævulinic acid.

**Lake bordeaux B.**  $\beta$ -Naphthylamine- $\alpha$ -sulphonic acid diazotised +  $\beta$ -hydroxynaphthoic acid.

**Lake red D.** Anthranilic acid diazotised +  $\beta$ -naphthol.

**Lake red P.** *p*-Nitraniline-*o*-sulphonic acid diazotised +  $\beta$ -naphthol.

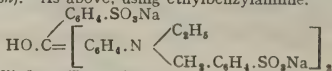
**Lanacyl blue 2B.** H acid diazotised + 1:4-aminonaphthol.

**Lanacyl violet.** H acid diazotised + ethyl- $\alpha$ -naphthylamine.

**Light blue.** See *Aniline blue*.

**Light green SF (bluish).** Benzaldehyde condensed with methylbenzylaniline sulphonated and oxidised.

**Light green SF (yellowish).** As above, using ethylbenzylaniline.



**Light Fast yellows.** Allied to *Tartrazine*.

**Lithol Fast scarlet R.** *m*-Nitro-*p*-toluidine diazotised +  $\beta$ -naphthol.

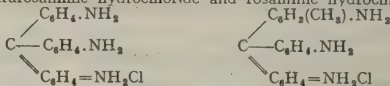
**Lithol red R.**  $\beta$ -Naphthylamine- $\alpha$ -sulphonic acid +  $\beta$ -naphthol.

**Lithol Rubine B.** *p*-Toluidine-*o*-sulphonic acid +  $\beta$ -hydroxy-naphthoic acid.

**Lyons blue.** See *Imperial violet*.

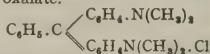
**Magdala red.**  $\alpha$ -Aminoazonaphthalene hydrochloride heated with  $\alpha$ -naphthylamine.

**Magenta.** Pararosaniline hydrochloride and rosaniline hydrochloride.



**Magenta S.** Sulphonated Magenta; sodium salt.

**Malachite green.** Benzaldehyde condensed with dimethylaniline by  $\text{ZnCl}_2$ ; oxidation gives tetramethyldiaminotriphenylcarbinol. Zinc chloride double salt, sulphate or oxalate.



**Manchester brown.** See *Phenylene brown*.

**Manchester yellow.** See *Martius yellow*.

**Mandarin G extra.** See *Orange II*.

**Marine blue.** See *Diphenylamine blue*.

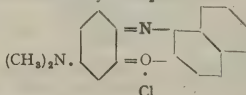
**Maroon.** Impure Magenta and Phosphine.

**Martius yellow.** 2:4-Dinitro- $\alpha$ -naphthol.

**Mauvein.** Oxidation of aniline containing toluidine. Phenyltolusafranine chloride,  $\text{C}_{27}\text{H}_{25}\text{N}_4\text{Cl}$ , or  $(\text{C}_{27}\text{H}_{25}\text{N}_4)_2\text{SO}_4$ .

**Melanogen blue D.** 1:5-Dinitronaphthalene treated with polysulphide.

**Meldola's blue.** Nitrosodimethylaniline hydrochloride and  $\beta$ -naphthol condensed in alcoholic soln. by  $\text{ZnCl}_2$ .



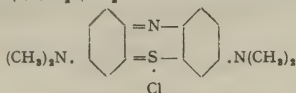
**Metanil yellow.** Metanilic acid diazotised + diphenylamine.

**Methyl Alkali blue.** Sulphonic acid of triphenylpararosaniline.

**Methyl blue.** See *Helvetia blue*.

**Methylene azure.** Alkaline soln. of *Methylene blue* exposed to air, loss of one methyl group.

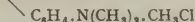
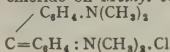
**Methylene blue.** Hydrochloride or zinc chloride double salt,  
 $2 \text{C}_{16}\text{H}_{18}\text{N}_3\text{SCl} + \text{ZnCl}_2 + \text{H}_2\text{O}$



**Methylene green.** Mononitro *Methylene blue* by  $\text{HNO}_3$  and  $\text{HNO}_2$ .

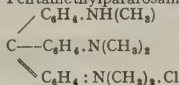
**Methylene violet.** Dimethyl-phenosafranin +  $\text{ZnCl}_2$ .

**Methyl green.** Methyl chloride on *Methyl violet*.



**Methyl orange.** Sodium or ammonium salt of *Helianthine*.

**Methyl violet B, 2B.** Pentamethylpararosanine hydrochloride.



**Methyl violet 6B, 7B.** See *Benzyl violet*.

**Methyl Water blue.** See *Helvetia blue*.

**Mikado golden yellow.** *p*-Nitroluene sulphonic acid oxidised in presence of  $\text{NaOH}$ . Dinitrostilbene disulphonic acid; sodium salt.

**Mikado orange.** *p*-Nitrostilbene sulphonic acid treated with  $\text{NaOH}$  and a reducing agent.

**Mikado yellow.** See *Stilbene yellow 8G*.

**Milling orange.** Aminoazobenzene sulphonic acid diazotised + salicylic acid.

**Modern blue (1900).** Leuco-compound of Gallamine blue.

**Modern blue CVI.** } Derived from Gallocyanine.

**Modern Cyanines.** }

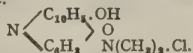
**Modern heliotrope PH.** Nitroso-monoethyl-*o*-toluidine condensed with gallamide; reduced to leuco-compound.

**Modern violet.** Leuco-compound of a Gallocyanine.

**Modern violet N.** Leuco-compound of a Pyrogallocyanine.

**Mordant yellow O.** See *Chrome yellow D*.

**Muscarine.** Nitrosodimethylaniline hydrochloride condensed with 2:7-dihydroxynaphthalene.



**Naphthalene Acid black.** Metanilic acid diazotised + Cleve's acids, diazotised +  $\alpha$ -naphthylamine.

**Naphthazarin S.** See *Alizarin black S*.

**Naphthindone.** See *Indoine blue R*.

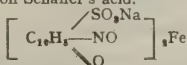
**Naphthol black B.** Amino G salt diazotised +  $\alpha$ -naphthylamine, diazotised + R acid.

**Naphthol black 6B.**  $\alpha$ -Naphthylamine disulphonic acid diazotised +  $\alpha$ -naphthylamine, diazotised + R acid.

**Naphthol blue B, D, R.** See *Meldola's blue*.

**Naphthol blue-black B, S.** *p*-Nitraniline diazotised + H acid (acid soln.), + aniline diazotised (alkaline soln.).

**Naphthol green B.**  $\text{HNO}_3$  on Schäffer's acid.

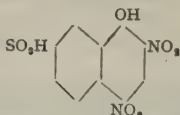


$\alpha$ -Naphthol orange. See Orange I.

$\beta$ -Naphthol orange. See Orange II.

Naphthol red. See Fast red.

Naphthol yellow S. Nitration of  $\alpha$ -naphthol-2:4:7-trisulphonic acid.



Naphthorubin.  $\alpha$ -Naphthylamine diazotised + Schöllkopf's acid.

Naphthylamine black D.  $\alpha$ -Naphthylamine disulphonic acid diazotised +  $\alpha$ -naphthylamine, diazotised +  $\alpha$ -naphthylamine.

$\alpha$ -Naphthylamine bordeaux.  $\alpha$ -Naphthylamine diazotised +  $\beta$ -naphthol.

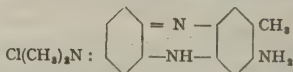
Naphthylamine yellow. See Martius yellow.

Naphthyl blue. Nitroso- $\beta$ -naphthylamine heated with aniline hydrochloride.

Naphthyl violet. Nitroso- $\beta$ -naphthylamine heated with  $\alpha$ -naphthylamine hydrochloride.

Naphthylene blue R. See Meldola's blue.

Neutral red. Oxidation of mixture of dimethyl-*p*-phenylenediamine and *m*-toluylenediamine; or soln. of Toluylene blue heated.



Neutral violet. As above, using *m*-phenylenediamine.

New blue B. New blue R condensed with dimethyl-*p*-phenylenediamine.

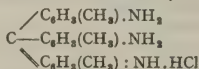
New blue R. Meldola's blue +  $\text{ZnCl}_2$ .

New Coccine. Naphthionic acid diazotised + G acid.

New Fast Cotton blue. See New blue R.

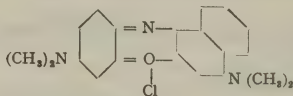
New green. See Malachite green.

New Magenta. From *o*-toluidine and formaldehyde. Triaminotritolylcarbino.



New Methylene blue N. From *p*-amino-monoethyl-*o*-toluidine and ethyltoluidine.

New Methylene blue NGG. Dimethylamine on Meldola's blue.



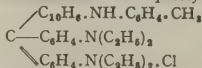
New red L. See Biebrich scarlet.

New Victoria blue B. See Victoria blue R.

New yellow. See Diphenylamine orange.

New yellow. See Fast yellow G.

Night blue. Ketone base condensed with *p*-tolyl- $\alpha$ -naphthylamine.

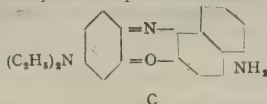


Nigrosine (spirit-soluble). Impure Induline. Nitrobenzene, aniline, aniline hydrochloride, and iron heated at about 180°C.

Nigrosine (soluble). Sulphonic acid of above.

*Nile blue.* Nitrosodimethyl-*m*-aminophenol condensed with  $\alpha$ -naphthylamine.

*Nile blue A.* Nitrosodiethyl-*m*-aminophenol condensed with  $\alpha$ -naphthylamine.

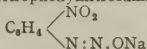


*Nile blue 2B.* As above, using benzyl- $\alpha$ -naphthylamine.

*p*-Nitraniline red. *p*-Nitraniline diazotised +  $\beta$ -naphthol on the fibre.

*Nitrazole.* *p*-Diazonitrobenzene sulphate +  $\text{NaHSO}_4$ .

*Nitrosamine red.* *p*-Nitrophenylnitrosamine, sodium salt.



*Opal blue.* See *Aniline blue*.

*Orange I.* Sulphanilic acid diazotised +  $\alpha$ -naphthol.

*Orange II.* Sulphanilic acid diazotised +  $\beta$ -naphthol.

*Orange III.* See *Methyl orange*.

*Orange No. 3.* *m*-Nitraniline diazotised + R acid.

*Orange IV.* See *Diphenylamine orange*.

*Orange G.* Aniline diazotised + G acid.

*Orange GRX.* See *Brilliant orange G*.

*Orange GS.* See *Orange IV*.

*Orange GT.* Toluidine diazotised + Schäffer's acid.

*Orange N.* See *Orange IV*.

*Orange P.* See *Orange II*.

*Orange R.* *o*-Toluidine monosulphonic acid diazotised +  $\beta$ -naphthol.

*Orange R extra.* See *Orange I*.

*Orange RN.* See *Orange G*.

*Orcelline.* Aminoazotoluene monosulphonic acid diazotised + N.W. acid.

*Orchil substitute V.* *p*-Nitraniline diazotised + naphthionic acid.

*Orchil substitute 3VN.* *p*-Nitraniline diazotised + L acid.

*Orient yellow.* See *Dianthine*.

*Oriol yellow.* See *Cotton yellow R*.

*Oxamine blue B.*

Dianisidine tetrazotised  $\begin{cases} \text{J acid.} \\ \text{N.W. acid.} \end{cases}$

*Oxamine blue 3R.*

Toluidine tetrazotised  $\begin{cases} \text{J acid (alkaline soln.)} \\ \text{N.W. acid.} \end{cases}$

*Oxamine red.*

Benzidine tetrazotised  $\begin{cases} \text{J acid.} \\ \text{salicylic acid.} \end{cases}$

*Oxamine violet.*

Benzidine tetrazotised  $\begin{cases} \text{J acid.} \\ \text{J acid (alkaline soln.).} \end{cases}$

*Oxyphenine.* Mixture of sulphonic acids of dehydrothiotoluidine and *Primuline* oxidised.

*Pæonin.* Crude Aurin heated under pressure with ammonia.

*Palatine black 4B.* S acid + 2 mols. diazotised *p*-toluidine (alkaline soln.), or 1 mol. diazotised sulphanilic acid (acetic acid soln.) + 1 mol. diazotised *p*-toluidine.

*Palatine Chrome black 6B.* 1-Amino-2-naphthol-4-sulphonic acid diazotised +  $\beta$ -naphthol.

*Palatine Chrome blue.* 1-Amino-2-naphthol-4-sulphonic acid diazotised +  $\alpha$ -naphthol.

*Palatine red.*  $\alpha$ -Naphthylamine diazotised +  $\alpha$ -naphthol-3 : 6-disulphonic acid.

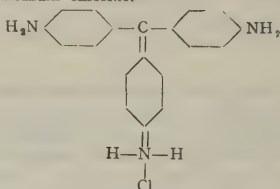
*Palatine scarlet.* *m*-Xylydine diazotised +  $\alpha$ -naphthol-3 : 6-disulphonic acid.

*Paramine brown.* Oxidation of *p*-phenylenediamine on the fibre.

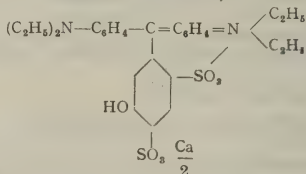
*Paramagenta.* See *Pararosaniline*.

*Para red.* See *p-Nitraniline red*.

*Pararosaniline.* Triaminotriphenylcarbinol, of which the hydrochloride is diaminofuchsonimonium chloride.



*Patent blue.* *m*-Hydroxybenzaldehyde condensed with diethylaniline sulphonated; converted into calcium salt; oxidised.

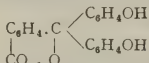


*Patent blue A.* As above, using ethylbenzylaniline.

*Perkin's violet.* See *Mauvein*.

*Permanent red 4B.* See *Lithol Rubin B*.

*Phenolphthalein.* Action of phthalic anhydride on phenol in presence of  $\text{ZnCl}_2$  or  $\text{H}_2\text{SO}_4$ .



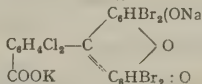
*Phenylene black.* See *Anthracite black*.

*Phenylene blue.* Simplest *Indamine*.

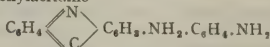
*Phenylene brown.* See *Bismarck brown*.

*Phenyl violet.* See *Imperial violet*.

*Phloxin.* Dichlorotetrabromo-fluorescein.



*Phosphine.* Diaminophenylacridine



and higher homologue nitrates or hydrochlorides

*Picric acid.* 1 : 2 : 4 : 6-Trinitrophenol.

*Pigment Fast red HL.* See *Helio Fast red RL*.

*Pigment orange R.* *p*-Nitro-*o*-toluidine diazotised +  $\beta$ -naphthol.

*Pigment purple.* *o*-Anisidine diazotised +  $\beta$ -naphthol.

*Pigment scarlet 3B.* Anthranilic acid diazotised + R salt.

*Polychromin B.* *p*-Nitrotoluene sulphonic acid and *p*-phenylene diamine treated with NaOH.

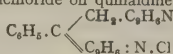


**Quinoline blue.** From amyl iodide, quinoline and lepidine; action of NaOH.

*Quinoline yellow.* Quinophthalone  $C_6H_4.CO : CH.C_6H_4N$ , or its sulphonic acids



*Quinoline red.* Benzotrichloride on quinaldine and isoquinoline in presence of  $ZnCl_2$ .



*Radial yellows.* Allied to *Xylene yellows*.

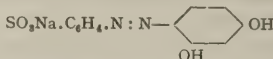
*Red corallin.* See *Pæonin*.

*Red violet 5R extra.* Triethyl magenta.

*Resazurin.* Oxidation of *Resorufin*.

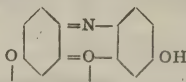
*Resorcin brown.* Xylidine diazotised } resorcinol.  
Sulphanilic acid diazotised }

*Resorcin yellow.* Sulphanilic acid diazotised + resorcinol.

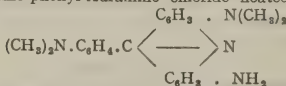


*Resorufamin.* Quinonedichlorimide condensed with resorcinol.

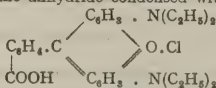
*Resorufin.*  $HNO_3$  containing nitrous fumes on ethereal soln. of resorcinol.



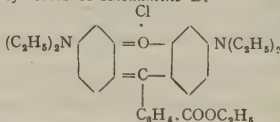
*Rheonine.* *m*-Amino-phenyl-Auramine chloride heated.



*Rhodamine B.* Phthalic anhydride condensed with diethyl-*m*-aminophenol.

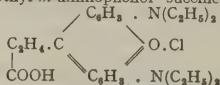


*Rhodamine 3B.* Ethyl ester of *Rhodamine B*.



*Rhodamine 6G.* Monoethyl-*m*-aminophenol phthalein, ethyl ester.

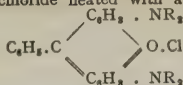
*Rhodamine S.* Dimethyl-*m*-aminophenol succinein.



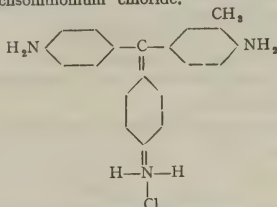
*Rhoduline red.* Safranin obtained by oxidation of 1 mol. *p*-aminomonethyl-toluidine, 1 mol. monoethyl-*o*-toluidine, and 1 mol. aniline.

*Roccelline.* See *Fast red A*.

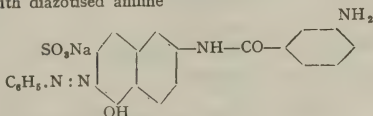
**Rosamines.** Benzotrichloride heated with a dialkyl-*m*-aminophenol.



**Rosaniline.** Triaminodiphenyltolylcarbinol, of which the hydrochloride is diaminomethylfuchsonimonium chloride.



**Rosanthrene O.** *m*-Nitrobenzoyl chloride condensed with J acid reduced coupled with diazotised aniline

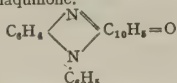


**Rosazine.** See *Azocarmine*.

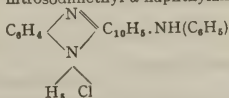
**Rose Bengal N.** Dichlorotetraiodo-fluorescein; potassium salt.

**Rose Bengal 3B.** Tetrachlorotetraiodo-fluorescein.

**Rosindone.** Rosinduline heated with HCl, or from *o*-aminodiphenylamine and hydroxynaphthaquinone.



**Rosinduline (phenyl).** Benzene-azo- $\alpha$ -naphthylamine, aniline, and aniline hydrochloride; or nitrosodimethyl- $\alpha$ -naphthylamine and aniline.



**Rosolic acid.** Methyl *Aurin*.

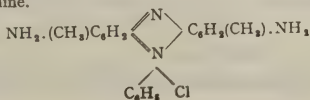
**Rubine.** Magenta free from arsenic.

**Rufigallol.**  $\text{H}_2\text{SO}_4$  on gallic acid, 1 2 3 : 5 : 6 : 7-hydroxyanthraquinone.

**Russian green.** See *Alsace green*.

**Safraniline.** See *Rhodamine B*.

**Safranine T.** *o*-Toluidine treated with nitrous fumes; oxidation. Oxidation of *p*-toluylenediamine and *o*-toluidine; condensation of Indamine obtained with *o*-toluidine.



*Scarlet EC.* See *Biebrich scarlet*.

*Scarlet GR.* Xylidine diazotised + Schäffer's acid; sodium salt.

*Setocyanine, Setoglaucine.* Allied to *Erioglaucine*.

*Soluble blue.* Aniline blue di- and tri- sulphonic acids; ammonium or sodium salts.

*Soluble blue XG.*  $\beta$ -Naphthylpararosaniline trisulphonic acid.

*Soluble Cotton blues.* Aniline blue tri- and tetra- sulphonic acids.

*Soluble Eosines.* Sodium and potassium salts of *Eosine*.

*Soluble primrose.* See *Erythrosine B*.

*Soluble Silk blue.* Aniline blue disulphonic acid.

*Soluble Sky blue.* See *Helvetia blue*.

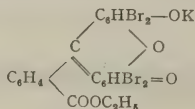
*Soudan G.* Aniline diazotised + resorcinol.

*Soudan III.* Aminoazobenzene diazotised +  $\beta$ -naphthol.

*Spirit blue.* See *Aniline blue*.

*Spirit Eosines.* See *Erythrines*.

*Spirit primrose.* Fluorescein brominated in alcoholic soln. and heated under pressure.



*Spirit Sky blue.* See *Diphenylamine blue*.

*St. Denis red.* Diaminoazoxytoluene tetrazotised + 2 mols. N.W. acid.

*Stilbene orange 4R.* See *Mikado orange*.

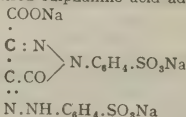
*Stilbene yellow 8G.*  $\text{CH} \cdot \text{C}_6\text{H}_3(\text{SO}_3\text{H}) \cdot \text{N} : \text{N} \cdot \text{C}_6\text{H}_3(\text{SO}_3\text{H}) \cdot \text{CH}$   
 $\parallel \qquad \qquad \qquad \parallel$   
 $\text{CH} \cdot \text{C}_6\text{H}_3(\text{SO}_3\text{H}) \cdot \text{NO}_2\text{NO}_2 \cdot \text{C}_6\text{H}_3(\text{SO}_3\text{H}) \cdot \text{CH}$

*Sulphur black T extra.* Dinitrophenol treated with aqueous soln. of polysulphide

*Sun yellow.* See *Curcumine S*.

*Tannin heliotropes.* See *Giroflé*.

*Tartrazine.* Sodium dioxycarbonate heated with 2 mols. phenylhydrazine  
 -*p*-sulphonic acid; or oxalacetic ether heated with phenylhydrazine  
 -*p*-sulphonic acid, diazotised sulphonic acid added, and saponification.



*Terracotta F.*

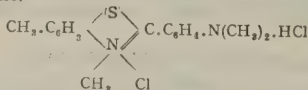
*m*-Phenylenediamine  $\left\{ \begin{array}{l} \text{diazotised Primuline.} \\ \text{diazotised naphthionic acid.} \end{array} \right.$

*Thiazol yellow G.* Dehydrothiotoluidine sulphonic acid diazotised + further mol. same.

*Thiocarmine R.* Diethyldibenzylthionine disulphonic acid.

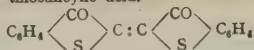
*Thioflavine S.* Sulphonated *Primuline*.

*Thioflavin T.* Dehydrothiotoluidine heated with methyl alcohol and HC under pressure.



*Thiogen dark red G, R.* } Azines fused with sodium polysulphide.  
*Thiogen purple.* }

**Thioindigo B.** From thiosalicylic acid.



**Thioindigo grey B.** 7:7'-Diamino-thioindigo.

**Thioindigo orange R.** 6:6'-Diethoxy-thioindigo.

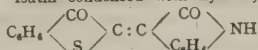
**Thioindigo pink BN.** 6:6'-Dibromodimethyl-thioindigo.

**Thioindigo red B.** See *Thioindigo B.*

**Thioindigo red 3B.** 5:5'-Dichloro-6:6'-dimethyl-thioindigo.

**Thioindigo red BG.** 5:5'-Dichloro-thioindigo.

**Thioindigo scarlet R.** Isatin condensed with hydroxythionaphthen.



**Thioindigo scarlet S.** 6:6'-Dithioxyl-thioindigo.

**Thioindigo violet 2B.** Dichlorodimethyldimethoxy-thioindigo.

**Thion blue B.** *p*-Nitro-*o*-amino-*p'*-hydroxydiphenylamine heated with CS<sub>2</sub> in alcoholic soln.; sulphurised.

**Thio Katigen colours.** Acetyl-*p*-phenylenediamine, or other *p*-diamine, nitro-acetanilide, &c., fused with sodium polysulphide.

**Thion brown.** Sulphur dyestuff from aniline-azo-*m*-toluylenediamine.

**Thion yellow G.** Thio-*m*-toluylenediamine heated with sodium sulphide soln.

**Thional bronze,** } Fusion of  $\beta$ -hydroxynaphthaquinone anilides with  
**Thional brown G, &c.** } sodium polysulphide.

**Thiophenol black T extra.** Dinitrophenol fused with polysulphides.

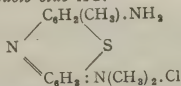
**Thiophosphine.** See *Chloramine yellow.*

**Thiophor bronze 5G.** Fusion of *p*-phenylenediamine and *p*-aminoacetanilide with sulphur.

**Thiophor bronze G.** As above, with addition of benzidine.

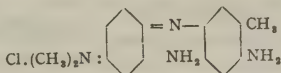
**Titan Comos.** See *Soluble blue XG.*

**Toluidine blue O.**

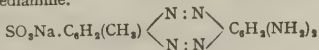


**Tolusafranin.** See *Safranin T.*

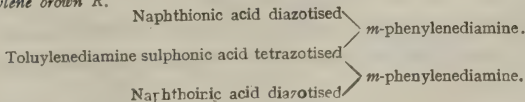
**Toluylene blue.** Oxidation of dimethyl-*p*-phenylenediamine and *m*-toluylenediamine; or action of nitrosodimethylaniline hydrochloride on *m*-toluylenediamine.



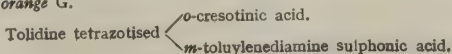
**Toluylene brown G.** 1 Mol. toluylenediamine sulphonic acid tetrazotised + 1 mol. *m*-phenylenediamine.



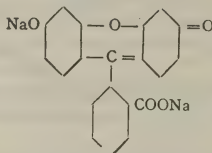
**Toluylene brown R.**



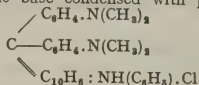
**Toluylene orange G.**



- Toluylene orange R.* Tolidine tetrazotised + 2 mols. *m*-toluylenediamine sulphonic acid.  
*Toluylene red.* See *Neutral red*.  
*Tropæoline G.* See *Metanil yellow*.  
*Tropæoline O.* See *Resorcin yellow*.  
*Tropæoline 2O.* See *Diphenylamine orange*.  
*Ultra violet dyestuffs.* Quinhydrones by condensation of a leuco-Gallocyanine with a Gallocyanine.  
*Uranine.* Sodium salt of fluorescein.



- Verde Italiano.* Fusion of *p*-aminophenol or its substituted derivatives with polysulphides in presence of copper sulphate at 180°–200°C.  
*Vesuvine.* See *Phenylene brown*.  
*Vesuvine B.* *m*-Toluylenediamine tetrazotised + 2 mols. *m*-toluylenediamine.  
*Victoria black B.* Sulphanilic acid diazotised +  $\alpha$ -naphthylamine, diazotised + dihydroxynaphthalene sulphonic acid S.  
*Victoria blue B.* Ketone base condensed with phenyl- $\alpha$ -naphthylamine.

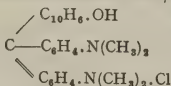


- Victoria blue R.* As above, using ethyl- $\alpha$ -naphthylamine.  
*Victoria blue 4R.* Methylated *Victoria blue B*.  
*Victoria violet 4BS.* *p*-Aminoacetanilide diazotised + 1 : 8-dihydroxynaphthalene-3 : 6-disulphonic acid; acetyl group saponified.  
*Vidal black.* Fusion of *p*-aminophenol or a *p*-diamine with polysulphide.  
*Violamine B.* See *Fast Acid violet B*.  
*Violamine G, R, 2R.* Aromatic amines condensed with fluorescein chloride may be sulphonated.  
*Violanthrone BS.* See *Indanthrene violet RT*.

- Violet black.* *p*-Phenylenediamine tetrazotised  $\left\{ \begin{array}{l} \alpha\text{-naphthylamine.} \\ \text{N.W. acid.} \end{array} \right.$

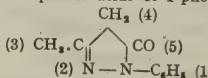
*Water blue.* See *Soluble blue*.

- Wool green G.* Ketone base condensed with  $\beta$ -naphthol; sulphonated.



- Wool scarlet R.* Xylidine diazotised +  $\alpha$ -naphthol-4 : 8-disulphonic acid.  
*Xanthine.* See *Phosphine*.

*Xylene yellows.* Dichloro sulphonic acids of 1-phenyl-3-methyl-5-pyrazolone.



- Xylidine orange.* See *Brilliant orange R*.

# IDENTIFICATION OF DYESTUFFS IN SUBSTANCE AND ON THE FIBRE.

## A. In Substance.

### *Detection of a Mixture.*

The majority of the available brands of dyestuffs are mixtures of two or more type-dyestuffs, or of one principal with one or more shading colours present in smaller quantities.

As examples of such mixtures may be mentioned :

(a) Acid dyestuffs : many of the Scarlets and Ponceaux, the Soluble and Alkali blues, the Acid violets, the Patent blue and Erioglaurine brands, several of the important Azo Acid blacks (Höchst).

In some cases dyestuffs are mixed in order to obtain a shade of a fastness which is not otherwise possible, *e.g.*, the Anthracyanines of Bayer, mixtures of Alizarin Saphirole with Azomagenta, Anthracyanine greens, mixtures of Alizarin Saphirole with Fast Light yellow, and the Anthracyanine browns, mixtures of Alizarin Saphirole with Fast Light yellow and Azofuchsine. These mixtures possess the advantage of good fastness to light combined with fairly good level dyeing capacity. In other instances a dyestuff of outstanding fastness to light which does not level very well may be mixed with another colour of similar shade, of somewhat inferior fastness to light, but good levelling capacity, the object being to obtain a mixture possessing both properties in a fair degree. Thus some of the Alizarin Direct blues (Höchst), and Alizarin Cyanol (Cassella) are mixtures of an Alizarin Saphirole colour with Patent blue or Cyanol.

(b) Substantive or salt dyestuffs : many of the Direct blues and blacks are mixtures of several types.

The Union and Duatol colours of Cassella are in many cases mixtures of direct and neutral dyeing acid colours designed to give a solid shade on union materials (wool and cotton), when dyed in a bath with addition of Glauber's salt.

Dyestuffs are frequently mixed in the powdered state, and the following simple tests will serve to detect whether a mixture is present :

1. A small amount of the powder is blown on to the surface of some concentrated sulphuric acid. The colour reactions which most coal-tar dyestuffs yield with concen-



trated sulphuric acid are so characteristic and varied that mixtures are frequently detected in this manner by the totally different colorations given by the particles of the various constituents of the admixture.

2. A further test is to dip small pieces of filter-paper into water, alcohol, dilute sulphuric acid, or dilute caustic soda, allow to drain for a moment, and then blow a minute quantity of the powdered dyestuff on to the various pieces of filter-paper. The particles of the different dyestuffs in a mixture will in the majority of cases give different colour reactions on the sheets of paper wetted with the various liquids given above.

These two tests alone will suffice to decide in most instances whether the sample consists of a single dyestuff or a mixture.

In case a solution is to be investigated, or the solid dyestuff has been produced by mixing the constituents in solution and subsequently evaporating to dryness, the above tests are not suitable, and the method of Goppelsröder is used. Long strips of filter-paper, from one to two inches wide, are suspended with the ends dipping into moderately dilute solutions of the dyestuff under examination, and allowed to stand if necessary for several hours. Different dyestuffs rise up the strips of filter-paper with varying velocities, and a mixture of dyestuffs in solution will often yield on standing a number of differently coloured zones on the strip, corresponding roughly to the various constituents of the mixture. These coloured zones may then be cut out, and further tested by spotting with the reagents used in the tables for the identification of individual dyestuffs referred to later. To confirm any indications of the presence of a mixture obtained by the above capillary test, and having ascertained the dyeing group or groups of the different colouring matters present as described later, small skeins of woollen, cotton, or tanned cotton yarn (as the case may require), are carefully dyed for a short time in the warm to boiling dyestuff-solution with the necessary additions of dilute acid or Glauber's salt, according to the class of dyestuff, acid, substantive, (etc.), previously found to be present. Each skein is dyed only for a short time, and is replaced by other skeins of material as the temperature rises, further additions of acid or Glauber's salt being made to gradually exhaust the bath. In this manner a fractional dyeing of the different skeins is effected, thus enabling the constituents of a mixture to be partially separated, the dyed hanks often assuming approximately the

different shades of the constituent colouring matters. The separation is only a very imperfect one, but is further aided by carrying out the test in neutral, acetic acid, and strongly acid, baths for wool, and with gradual addition of Glauber's salt to the dyebath in the case of direct cotton dyestuffs.

### *Preliminary tests.*

Where the character of an unknown dyestuff is to be investigated, the following preliminary dye-trials may be made :

1. Boil a solution of a small quantity of the dyestuff acidified with acetic acid, with small pieces of woollen and of tanned cotton yarn together in a test-tube for a minute or two, then decant, and wash with cold water. Under these circumstances, basic dyestuffs mainly colour the tanned cotton, whereas acid and substantive colours dye the wool, leaving the tanned cotton much less tinted.

2. Boil a solution of the dyestuff to which a little Glauber's salt has been added with a small piece of unmordanted bleached cotton yarn for a few minutes, decant, wash two or three times with cold water, heat almost to the boil with a small quantity of water, after which again rinse once with cold water. Substantive colours dye the cotton a full shade, which does not lose much of its colour when heated nearly to the boil with a small amount of water for half a minute.

According to the result of the above two tests further elaboration is possible, as follows :

- (1) If an acid colour has been found, further trials may be made to dye wool in a neutral bath with addition of Glauber's salt, also in a bath made faintly acid with acetic acid, and in a bath strongly acidified with sulphuric acid. Among the colours which dye wool in a neutral bath may be mentioned the Sulphoncyanines and Sulphon Cyanine black, also the similar Alphanol blues and blacks of Cassella, Wool Fast black B (Badische), Indocyanines (Berlin), Alkali violets and blues, and the substantive colours in general; also many acid colours which are also used in wool dyeing from a strongly acid bath, such as the Fast and Naphthol reds, Orange II, Wool green S, Patent blue, Acid violets, etc. Attempts may also be made to prepare dyeings according to the one-bath or after-chroming method. With many of the after-chrome colours, the direct is totally different in shade to the chromed dyeing; thus the red Chromotropes (Höchst)

become blue-black on after-chroming. This is often a valuable indication of the nature of the colour under investigation.

(2) If a substantive colour has been found, further trials may be made to discover whether the dyestuff is one intended for the diazotising and developing process, or for after-treatment with formaldehyde, metallic salts, etc.

In case the dyestuff is in the form of a paste, it may be, but is not necessarily, a mordant colour, and trials may be carried out to dye it on chrome mordanted loose wool, also on calico printed with various mordants.

If the dyestuff is not soluble in the usual solvents an attempt is made to dye the colour on cotton yarn in a boiling bath containing sodium sulphide and common salt. Apart from the Sulphur dyestuffs, a number of the vat dyes, including Hydron blue, olive and brown, also Thioindigo red, Indanthrene yellow and violet BN extra, would dye the cotton under these conditions. In order to confirm the presence of a Sulphur dyestuff, the dyeing is well washed, boiled out with water several times, then once with 10 per cent. caustic soda solution to remove any finely divided sulphur present, again well washed with water, dried, and a small cutting heated with stannous chloride solution strongly acidified with hydrochloric acid. The top of the test-tube is covered with a close-fitting cap of filter-paper in the middle of which one drop of lead acetate solution has been placed. After warming, the tube is allowed to stand some time. If a Sulphur dyestuff is present, the filter-paper, especially the under side of the lead acetate spot, will be coloured brown. With the exception of Hydron blue and a few sulphurised vat dyestuffs, the vat colours do not give this reaction. A further portion of the dyeing is immersed in dilute bleach liquor and allowed to stand. A rapid discharge of the colour indicates the presence of a Sulphur dyestuff. In this manner Hydron blue may be distinguished from an ordinary Sulphur blue, as its dyeing remains practically unaltered in the bleach liquor. Finally the reduction test with alkaline hydrosulphite, described later, may be performed on the sample of dyestuff, in order to determine whether it is a vat colour.

Having decided by means of the above tests to which dyeing group the unknown dyestuff belongs, it is desirable as a further guide to its identification, to determine the chemical relationship of the colour. This may be accomplished with the aid of a scheme worked out by Weingärtner in 1887, and later further elaborated and

extended by A. G. Green. (For tables see "Manual of Dyeing," by Knecht, Rawson and Löwenthal, Vol. II.)

The use of this scheme is simplified by having previously determined the dyeing group to which the unknown colour belongs, as already described.

### Group I. Dyestuffs soluble in water.

#### (a) *Basic dyestuffs.*

A basic dyestuff found in the dyeing tests may be confirmed by just acidifying a dilute solution with acetic acid, adding a small amount of tannic acid solution, when a coloured precipitate is formed. Dyestuffs of the Gallocyanine class, also the Triphenylmethane mordant colours used in printing only give a finely divided precipitate slowly with tannic acid solution.

A moderately strong solution of the dyestuff is reduced with zinc dust and dilute hydrochloric acid. The zinc is allowed to settle a moment, and the clear liquor poured off on to a piece of filter-paper, which is suspended to drain.

I. In case the original colour returns immediately on exposure to air, the basic dyestuff belongs to the class of Azine, Oxazine, Thiazine or Acridine colours. Of these, Thiazine dyestuffs may be detected by heating to redness a small amount of the powdered dyestuff mixed with pure lime in a crucible, dissolving the cooled mass in hot dilute nitric acid, filtering if necessary, and testing the filtrate for sulphate with barium chloride solution. Acridine colours, which are mostly orange and yellow, dissolve in concentrated sulphuric acid with a bright green fluorescence. The chief members of these four "Azine" groups are:

*Red.* Safranine, Rhoduline red and Brilliant Rhoduline red B (Bayer), Magdala red (Durand), Neutral red (Cassella), Pyronine and Acridine red (Leonhardt).

*Orange and Yellow.* Phosphine, and the related Patent Phosphine (Soc. Chem. Ind.), Paraphosphine and Diamond Phosphine (Cassella), Rheonine (Badische), Flavophosphine (Höchst), Aurophosphine (Berlin), also Acridine orange NO (Leonhardt), Acridine yellow (Leonhardt) and Benzoflavine (Griesheim-Oehler).

*Green.* Azine green (Leonhardt).

*Blue.* Methylene blue, New Methylene blue N (Cassella) Thionine blue (Höchst), Gentianine (Geigy), New blue or Meldola's blue, Muscarine (Durand), Nile blue A (Badische), New Methylene blue GG (Cassella), Capri blue (Leonhardt), Cresyl blue, Brilliant Cresyl blue 2 B (Leonhardt), Neutral blue (Cassella), Basle blue R and 2 B (Durand), Indazine M

(Cassella), Metaphenylene blue (Cassella), Paraphenylene blue (Durand), Toluylene blue (Griesheim-Oehler), Indamine blue (Höchst) and Methyl Indone B and R (Cassella).

*Violet.* Mauve, Neutral violet and Fast Neutral violet (Cassella) Tannin heliotrope (Cassella) and the similar Safranine MN (Badische), Paraphenylene violet (Dahl), Prune pure (Sandoz).

II. If the original colour returns very slowly or not at all on exposure to air, but returns on spotting with 1 per cent. chromic acid solution, the dyestuff belongs to the class of Basic Phthaleins and Triphenylmethane colours. The former yield powerfully fluorescent aqueous solutions, and the colour of Rhodamine B in the above test returns much more quickly than that of Magenta; with Victoria blue B a much greener shade than the original is obtained on reoxidation. The chief dyestuffs of this group are:

*Red.* Diamond Magenta, and the impure brands Cerise, Grenadine, Cardinal, Russian red, etc., Rhodamine B, G, 3 B, and 6 G (Badische and Soc. Chem. Ind.), Irisamine G (Cassella), Rhodamine S (Badische and Soc. Chem. Ind.).

*Green.* Methyl green, Malachite green, Brilliant green, Victoria green 3 B.

*Blue.* Victoria blue B and 4 R and Victoria pure blue B (Badische), Victoria blue R (Badische), Night blue (Badische and Soc. Chem. Ind.), Glacier blue (Soc. Chem. Ind.), Setoglauanine, Setocyanine, and Setopaline (Geigy), Turquoise blue G and 2 B. (Bayer).

*Violet.* Methyl violet R to 5 R, Methyl violet B and 2 B, Methyl violet 6 B, Crystal violet (Badische and Soc. Chem. Ind.), Ethyl purple (Badische and Soc. Chem. Ind.).

III. If the original colour does not return even on the addition of chromic acid, the dyestuff may be one of a number of basic Azo dyestuffs such as Chrysoidine, Bismarck brown, Tannin orange (Cassella), New Phosphine, Azo Phosphine, etc. The yellow Thioflavine T (Cassella) belongs to the Thiobenzenyl group which are only reduced with great difficulty. The reduced solution of Auramine on filter-paper gives a fine violet when the paper is warmed over a flame until dry. The Safranine-Azo dyestuffs Indoine blue and Naphthindone yield the pink colour of Safranine immediately on exposure to air after this reduction test.

The isolation of the basic dyestuffs for further examination may also be effected by making the aqueous solution alkaline with caustic potash and shaking out with ether. The bases are liberated and pass into solution in the ether. The latter



is now washed once or twice with very dilute caustic soda and then with dilute acetic acid 5 per cent., which extracts the bases from solution in the ether. The acetic extract can now be concentrated for further examination. Differences in the basicity of these dyestuffs may be made use of in their separation as follows: The aqueous solution is first extracted with ether. Such colours as Chrysoidine, Bismarck brown, Rhodamine S, Victoria blues B, R, and 4 R, etc., are already dissociated in aqueous solution and the base passes into the ether. One per cent. ammonia is now added and the extraction continued with fresh ether. The weak alkali liberates the bases of Induline, Oxazine and Acridine dyestuffs which are extracted. The dilute ammonia is followed by strong ammonia which liberates Magenta, and finally by caustic potash which sets free the Safranin bases, and these can be extracted in their turn. This separation is naturally only an approximate one.

(b) *Acid and Substantive Dyestuffs.*

The aqueous solution is reduced with zinc dust and ammonia, and poured on to filter-paper.

1. If the solution is decolorised, but the colour returns on exposure, this indicates sulphonated Azines, Oxazines, Thiazines, etc., including Soluble Indulines and Nigrosines, Azo-Carmine (Badische) and Rosinduline (Kalle), Thio-carmine (Cassella), soluble Gallo-cyanines (leuco or bisulphite compounds), Phenocyanines, Gallo Navy blue, Gallophenine, etc., or sulphonic acids such as Delphine blue, Gallanil indigo and violet, Brilliant Alizarin blues R, G, B, 3 R (Bayer). Indochromine (Sandoz), Indocyanine (Berlin), also Indigo Carmine. The Brilliant Alizarin blues and Indigo Carmine give yellow solutions on reduction.

II. If original colour does not return spontaneously, but only on addition of chromic acid and exposure to ammonia vapour, a further separation is effected by acidifying the dye-solution and shaking out with ether:

1. The ether extracts the colour-acid, leaving the aqueous solution almost colourless. Indicates Phthaleins and Aurines, mostly giving highly fluorescent solutions, including Uranine, Chrysoline, Eosine, Erythrosine, Phloxine, Rose Bengal, Cyclamine, Aurine, Coralline. To further identify, test original colour for chlorine, bromine and iodine, by calcination with pure lime, followed by the usual qualitative tests for chloride, bromide and iodide.

2. Ether remains colourless.

Dyestuff belongs to the large class of sulphonated Triphenylmethane colours, which includes such important

dyestuffs as Acid Magenta, Acid greens, Cyanole Fast green G (Cassella), Naphthalene green V (Höchst), Erio green (Geigy), Light green S, Wool green S, Neptune green, Agalma green (Badische), Guinea green (Berlin), Fast green bluish (Berlin), etc.; also Patent blue (Höchst), Erioglaucine and Eriocyanine (Geigy), Cyanole and Tetracyanole, Brilliant Milling blue and green (Cassella), Neptune blue (Badische), Brilliant Acid blues, Acid violets, Formyl violet, Alkali and Soluble blues, Brilliant Wool blues. Also the important Triphenylmethane mordant dyestuffs of Geigy and Bayer, viz., Chrome violet, Eriochromazurol (Geigy), the Chromoxan colours (Bayer).

III. In case the solution is decolorised in this reduction test, and the colour does not return, even on oxidation of the reduced liquid on filter-paper with chromic acid, then this points to the presence of those groups of dyestuffs which are destroyed on reduction, viz., the Nitro-, Nitroso-, Azo-, and Hydrazine colours.

The Nitro-dyestuffs, other than picric acid, which is almost obsolete as a dyestuff although employed in the production of important afterchrome dyestuffs such as Metachrome brown (Berlin), include Naphthol yellow S, the Nitro-Azo colours, Azoflavine (Badische) and Indian yellow (Bayer), also the above Metachrome brown derived from picraminic acid. These dyestuffs usually deflagrate when heated on platinum foil.

The Nitroso-dyestuffs, principally used in calico-printing in conjunction with iron and chrome mordants, are usually in the form of pastes sparingly soluble in water. They include Fast green, which is dinitrosoresorcin, also Viridone FE (Höchst), which yields a far brighter green than dinitrosoresorcin on iron mordant, and Chrome bistre NO (Höchst), also used in printing, giving deep brown shades on chrome mordant. The older Gambines (Holliday) and Dioxine (Leonhardt) seem to be but little used. This class also includes an acid dyestuff, Naphthol green B (Cassella), of great fastness to light, and employed in dyeing carpet yarns. A colour belonging to this group can be detected by Liebermann's test for nitroso-compounds. A very small amount is warmed together with some phenol and conc. sulphuric acid, after which the mixture is cooled, diluted with water and made alkaline with caustic potash. An intense blue coloration is obtained.

Besides the small groups of Nitro- and Nitroso-dyestuffs, the Hydrazine colours, mostly yellows, and including Tartrazine, Fast light yellows (Bayer), Flavazines (Höchst).



Xylene light yellow (Sandoz), etc., the extensive group of Azo-dyestuffs are also destroyed in the reduction test with zinc dust and ammonia. The dye-trials previously performed will have shown whether the Azo-dyestuff, if present, is an acid or substantive colour. A closer identification can in this case only be attained by use of tables giving the reactions of individual dyestuffs.

Among the acid and substantive colours are several groups which are not decolorised by zinc dust and ammonia. Perhaps first in importance among these are the Acid and Soluble Alizarin dyestuffs (bisulphite compounds). All these on reduction yield a red to brown vat, and the reduction in these cases is preferably carried out in the cold. The Acid Alizarins are generally of outstanding fastness to light and include Alizarin Saphirole B and SE, Alizarin Astrole B and G, Alizarin sky blue B, Alizarin Uranole R and B, Alizarin Irisole R, Alizarin Rubinole R, GW, 3 G, 5 G, Alizarin Cyanine green G extra and 3 G, Alizarin Viridine, Brilliant Alizarin Cyanine 3 G and 2 G, Alizarin blue black B and 3 B (Bayer), also Cyananthrol R, Anthraquinone blue SR extra, Anthraquinone violet and Anthraquinone green GXN, Anthracene blue SWGG (Badische), Alizarin Direct blue B, Alizarin Direct green, and Alizarin Direct violet, Acid Alizarin blue GR and 2 B (Höchst). If the group test point to an acid Anthraquinone colour (red-brown vat on reduction), the shade obtained on woollen yarn in the dyeing test will enable the exact colour to be singled out from the above list in most cases. Also use may be made of the fact that Alizarin sky blue B (Bayer) and Anthraquinone blue SR extra (Badische) contain combined bromine in the molecule for the detection of these two colours.

This class includes Alizarin S, which dyes on chrome-mordanted wool, or according to the afterchrome process, also the soluble bisulphite compounds, Alizarin blue S, Indigo blue S, green S (Badische), also Coerulein S and Alizarin black S. These compounds form dark pastes or liquids with the smell of sulphur dioxide, which is evolved when a sample is acidified and warmed. Here again the shade obtained in the dyeing tests is of great assistance in the identification of the exact colour.

A further group of dyestuffs which are reduced very slowly or not at all by zinc dust and ammonia are the Thiobenzoyl colours, which remain yellow on reduction. These include the substantive yellows Thiazol and Clayton yellows, Mimosa, Primuline, Oxyphenine, Diamine fast

yellow B, FF', Chloramine yellow, Thioflavine S, and also the acid dyestuff Quinoline yellow, not belonging to the latter class. The Thiobenzoyl-Azo-colours, Erica (Berlin), Brilliant Geranine (Bayer), etc. (direct cotton dyestuffs), also give on reduction a yellow liquid, due to destruction of the azo-group.

## Group II. Dyestuffs insoluble in water.

A small sample is warmed with 5—10 per cent. caustic soda solution

### I. The colour does not dissolve.

Another sample is tested for solubility in alcohol :

(a) Dyestuff soluble in alcohol, solution not fluorescent. This sub-group includes Spirit Indulines and Nigrosines belonging to the Azine group—reduction test with zinc dust and a few drops of conc. ammonia in alcoholic solution, colour returns on pouring reduced solution on filter-paper; also Spirit blue (triphenylmethane), colour returns on oxidation on filter-paper with a 1 per cent. solution of chromic acid in glacial acetic acid. This group also includes many of the oil-colours, such as Soudan red (Fast red T (Geigy)), Oil reds B and G, Oil blacks, Typophor red, carmine and violet (Badische), etc., for the most part Azo-colours destroyed in alcoholic solution by alkaline reducing agents.

(b) Dyestuff soluble in alcohol, solution fluorescent. Colour present is one of the Spirit Eosines, Cyanosine, or Magdala red (rarely met with).

(c) Dyestuff insoluble in alcohol.

This group includes the numerous vat dyestuffs, which may be further classified into three principal groups : 1. Indigoid ; 2. Anthraquinone ; 3. Other vat dyestuffs.

1. The Indigoid dyestuffs include Indigo, Brilliant Indigo dyestuffs (Badische), Ciba colours (Soc. Chem. Ind.), Helindone colours (Höchst), which are identical with the Thioindigo series (Kalle), and also a few of the Algal dyestuffs of Bayer. On reduction with a warm 10 per cent. solution of Hydrosulphite conc. powder made strongly alkaline with caustic soda these dyestuffs give yellow-coloured vats. They are also soluble to a greater or less extent with characteristic colours (sometimes fluorescent, especially the reds) in boiling benzene, pyridine, and glacial formic and acetic acids. For this latter test a sample of the paste is dried in the air-oven at 120°C.

2. The Anthraquinone vat dyestuffs include the Indanthrene and Algal groups.

In this case the reduction product or vat with warm alkaline hydrosulphite solution is with most of the dyestuffs, excepting the blues (which yield blue leuco-products), very characteristic, being deeper and in most cases totally different in shade—usually deep blue, violet, red or orange—from the dyestuff or the dyeing produced with it.

The Anthraquinone colours are insoluble or only very slightly soluble in boiling benzene, pyridine, and glacial acetic and formic acids.

-3. Other vat dyestuffs. These include the vat dyestuffs prepared from anthraquinone, benzanthrone and carbazol derivatives by fusion with sulphur or polysulphide, and include Hydron blue, olive and brown (Cassella), (the two latter apparently identical with Indanthrene olive and brown), also probably some of the Cibanone colours, Cibanone black (Soc. Chem. Ind.). The reactions of these dyestuffs resemble those of the Anthraquinone group, but are less characteristic. Hydron blue also yields a yellow vat, whereas Hydron olive and brown resemble Sulphur colours in being partly or wholly discharged by immersion of the dyeings in bleach liquor (hypochlorite). The identification of the vat dyes individually may be facilitated by also noting in addition to the above tests the shade obtained when the sample is dyed on cotton yarn; also the coloration, which is often very characteristic, obtained by solution in concentrated sulphuric acid.

The test which has been proposed for identifying these colours on the fibre, viz., heating in a dry tube and noting the colour of any vapour or sublimate produced, does not appear to be very characteristic for colours other than Indigo and its halogen derivatives (violet vapours), but as a general test for the Indigoid vat colours it is somewhat uncertain. The Brilliant Indigo and Ciba blue dyestuffs (brom- and chlorobrom-Indigo) may be further distinguished from Indigo by heating with pure lime, dissolving the cooled mass in boiling dilute nitric acid, and testing for chloride and bromide in the filtrate. In this case the Indigo may advantageously be heated in a porcelain boat in a hard glass tube, and the vapour carried by a stream of air or oxygen over a layer of red-hot lime.

II. The colour is soluble in caustic soda.

The reduction test with zinc dust and ammonia is now carried out on a fresh sample.

(a) A brown vat is obtained which when poured on to filter-paper reoxidises to the original colour. This group includes Gallein, Coerulein, Gallocyanine, Gallamine blue, Galloflavine, Reso flavine, Alizarin blue and black, Anthracene blues and Alizarin Cyanines, all dyestuffs which are generally met with in the form of 20 per cent. pastes. Alizarin blue gives a bright red reduction product.

(b) A brown vat is obtained, but on pouring on to filter-paper the original colour does not return, but the colour of the alkaline salt of the dyestuff is obtained, (*e.g.*, with Alizarin, violet). On spotting with dilute sulphuric acid on the filter-paper, this yields the original colour except with Alizarin orange. This group includes Alizarin, Anthrapurpurine, Flavopurpurine, Alizarin Bordeaux, Alizarin orange and Anthracene brown. The reduction test with Alizarin dyestuffs, as noted previously in considering the Acid Alizarins, is best performed cold to avoid over-reduction.

In this group may also be included the pigment Azo-dyestuffs such as Lithol red R, Lithol Fast scarlet (Badische) which are soluble in boiling alcohol and also in hot alcoholic ammonia.

It is to be noted that in most cases it will only be necessary to carry out a selection of the tests described before the dyeing group and chemical relationship of the unknown colour have been ascertained, when it will generally be a question of quite a small number of possible individual dyestuffs. For more exact identification at this stage, use may be made of the various tables of the reactions of dyestuffs with various reagents, previously referred to. Such tables have been compiled by Schultz and Julius, "Tabellarische Uebersicht der künstlichen Farbstoffe."

## B. On the Fibre.

The investigation of dyestuffs on the fibre presents an even more difficult problem than the examination of the dyestuffs themselves, for two reasons. In the first place, the majority of dyed shades have generally been produced with a number of dyestuffs, often belonging to different classes, both chemically and from the dyeing standpoint. Secondly, the large number of methods now in use for after-treating dyeings with the object of fixing the dyestuff more firmly on the material renders it impossible in many cases to strip the dyed fabric and examine the resulting dye-solution according to the methods described in Section A.

It is only necessary to identify the chemical class or classes

of the dyestuffs which have been employed and to which dyeing groups they belong in order to be able to select dyestuffs to produce the same shade and fastness as the dyeing to be matched. In certain cases it is, however, essential to determine the actual dyestuffs used in obtaining a particular shade.

#### *Presence of Mordant.*

It is first ascertained whether the dyestuff has been fixed on the fibre with the aid of a mordant. The following metals may be present : Lead, copper, antimony, tin, aluminium, iron, chromium, titanium, zinc, manganese, nickel, cobalt, calcium, and magnesium.

As a rule lead is only present on cotton dyeings, as Chrome yellow or Chrome orange, alone or in combination with an Indigo ground to produce a green shade.

Antimony is only present on cotton dyeings, in conjunction with basic dyes. Manganese oxide is used in producing Manganese bistre on cotton. Calcium may be present as an assistant mordant in the case of many Alizarin dyeings and prints on cotton.

The other metals mentioned are employed in the form of their salts as mordants and fixing agents in connection with various classes of dyestuffs on both wool and cotton.

Before the analysis of the ash is undertaken it is advisable that the material to be investigated should be thoroughly washed in hot water.

As the amount of metallic oxide present on the material may be very small (especially is this the case with coppered dyeings on wool and cotton materials), a large piece of the dyed material is cut into small pieces, and packed into a large porcelain crucible, which is then covered with the lid, and heated, at first gently and then afterwards more strongly up to a bright red heat over a Méker burner. When decomposition is complete, the lid is removed, and the bulk of the carbonaceous matter allowed to burn away. Finally, in order to get rid of the last traces of carbon, the crucible is cooled, a small amount of potassium chlorate is added and again heated. The residue is allowed to cool, and is then warmed with small amounts of aqua regia, the mass being broken if necessary with a glass rod and each extract decanted into a porcelain dish. The extracts are diluted with water, raised to the boil, and filtered, and the residue extracted with small amounts of boiling water. The extract is then evaporated almost to dryness, and the residue dissolved in a very small amount of water, and analysed according to the usual scheme of qualitative analysis.



In case the residue is insoluble in aqua regia, it may contain the oxides of tin, aluminium, chromium, iron, or titanium, which are practically insoluble in acids after strong ignition, and remain in the residue after the treatment with aqua regia. Any such residue is examined according to the usual analytical methods. (See "Qualitative Analysis," Vol. I.)

The filtrate is made alkaline with ammonia, any iron present filtered off, acetic acid added until the solution is faintly acid, and then a few drops of potassium ferrocyanide solution added. The production of a reddish-brown precipitate or coloration indicates the presence of copper.

In testing for iron, it is to be remembered that all wool dyeings give the reactions for iron to some extent due to the presence of combined iron oxide in the natural wool fibre.

In case the presence of a mordant is detected an indication is immediately obtained of the nature of the dyestuff present on the wool or cotton material; the shade is also taken into consideration. The presence of chromium in wool dyeings indicates Alizarin dyestuffs on chrome mordant or one of the very numerous after-chrome colours. As a general rule the presence of chromium in cotton dyeings indicates after-treated substantive dyeings, or possibly Alizarin blue dyed on cotton yarn. In case lead is present with chromium, the presence of Chrome yellow is probable. Copper on dark-blue wool dyeings probably indicates an Indigo ground topped with such coppered colours as Erio fast purple (Geigy), Omega claret (Sandoz), Topping violet (Badische), etc.

Copper on cotton dyeings indicates after-coppered substantive or Sulphur colours. Iron on wool dyeings in large amount indicates Logwood black. Iron on cotton dyeings also indicates Logwood black or Alizarin violet.

Iron and chrome together on cotton may indicate mineral khaki, alone or topped with Sulphur colours. Manganese is present as Manganese bistre.

Iron oxide on fawn or biscuit dyeings indicates that these are due to Iron buff. Iron oxide on blue cotton dyeings may indicate the presence of Prussian blue.

Antimony on cotton dyeings indicates the presence of basic dyestuffs.

Other metals (tin, aluminium, zinc, nickel, cobalt, iron, and chromium, and in rare cases copper) would be met with in fast calico prints made with Alizarin and Nitroso dyestuffs.

In case tin is present in woollen dyeings: scarlet indicates cochineal; bright lemon yellow, green, etc., dyeings, probably Persian berries, weld, etc., alone or in combination. Alumina in conjunction with scarlet dyeings on wool, Alizarin red, etc.

Precautions must, however, be taken before correct conclusions can be drawn from the presence of metallic oxides on textile materials. Thus alumina is often applied as a water-proofing material to both cotton and woollen goods, iron salts and tannin are employed to cover burls in black woollen piece goods, etc.

Having determined the nature of any mordant, the procedure depends largely on whether cotton or wool dyeings are under examination :

### 1. Dyeings on Vegetable Fibres.

The various substantive Azo-dyestuffs on cotton, also after-treated and developed according to the various methods, are quickly decolorised when boiled with a dilute solution of titanous chloride (Knecht). Primuline red is discharged to yellow. Paranitraniline red is decolorised on boiling for two minutes,  $\alpha$ -Naphthylamine claret requiring longer. The simple undeveloped thio-benzenyl dyestuffs (all yellow or orange) are unaffected by this reagent. Most basic colours dyed on tannin and antimony mordant are destroyed, and the material is left of a dull yellow brown colour due to titanium tannate. With a few colours, *e.g.*, Rhodamine, Thioflavine T, etc., the colour returns on rinsing thoroughly or on immersion in dilute hydrogen peroxide. The Sulphur colours rapidly turn brown or of a drab colour, and hydrogen sulphide is evolved. The original colour returns on washing and exposure to air, or on treatment with dilute hydrogen peroxide. Aniline black also becomes a drab shade, but the black returns on washing and exposure. Indigo is at first converted into Indigo white, but on continued boiling is further reduced and completely destroyed. This test can thus be used for detecting sulphur colours on cotton in presence of Indigo. Prussian blue is instantly decolorised by titanous chloride, but the colour returns on washing in water and exposure to air. Iron buff is quickly reduced and removed as ferrous salt. Turkey red (Alizarin) becomes a maroon in consequence of formation of the titanium lake of Alizarin.

Titanous chloride can also be used for the detection of mixed dyeings. For example, cotton dyed green with Direct Sky blue and Chrysophenine on careful reduction turns blue owing to complete destruction of the yellow, whilst the blue remains unaffected under these conditions.

G. E. Holden (*Journ. Soc. Dyers and Colourists*, 1909, p. 47) recommends titanous chloride as a useful reagent for the detection of colours dyed on cotton. As further tests, he



immerses portions of the dyeings to be investigated in cold chloroform, and also in bleaching powder solution (5° Tw.) to which dilute acetic acid is gradually added.

|                                | Titanous<br>chloride.                  | Bleaching Powder<br>Soln. (5° Tw.) and<br>acetic acid. |
|--------------------------------|--|--|
| Algol blue CF                  | Garnet                                 | Green  |
| Algol blue 3G                  | Dull drab                              | Gradually discharged.                                  |
| Algol dark green B             | Reddish brown                          | Light yellow brown.                                    |
| Algol green B                  | Reddish blue                           | Discharged.  |
| Algol red B                    | Brown                                  | Gradually bleached to<br>salmon shade.                 |
| Alizarin blue                  | Dull black                             | Discharged.  |
| Alizarin red                   | Maroon                                 | Discharged.  |
| Azo pink BB                    | Discharged                             | Discharged.  |
| Bromindigo FB                  | Olive                                  | Weakened in shade.                                     |
| Chloranisidine                 | Discharged                             | Very slowly discharged.                                |
| Ciba blues                     | Olive                                  | Weakened in shade.                                     |
| Ciba red B                     | Discharged                             | Unaffected.  |
| Ciba violet B                  | Discharged                             | Gradually lighter in<br>shade.                         |
| Ciba violet R                  | Discharged                             | Unaffected.  |
| Helindone red 3B               | Dull violet                            | Red violet.  |
| Helindone red 3B and<br>Indigo | Duller violet                          | Blacker in shade.                                      |
| Indanthrene blue BO            | Reddish brown                          | Blacker in shade.                                      |
| Indanthrene blue BT            | Black                                  | Bluish green.  |
| Indanthrene blue RC            | Garnet                                 | Green.   |
| Indanthrene blue RS            | Maroon                                 | Becomes gradually<br>brown.                            |
| Indanthrene claret G           | Brown                                  | Dull brown.  |
| Indanthrene green B            | Garnet                                 | Becomes a more<br>brick-red shade                      |
| Indanthrene red R              | Reddish brown                          | Duller in shade.                                       |
| Indanthrene violet R           | Garnet                                 | Redder in shade.                                       |
| Indanthrene violet RT          | Maroon                                 | Discharged   |
| Indigo blue                    | Yellow tint                            | Unaffected.  |
| Paranitraniline red            | Discharged                             | Unaffected.  |
| Paranitroorthoanisidine        | Discharged                             | Slowly lighter in<br>shade.                            |
| Thioindigo red B               | } Practically<br>discharged            | Red colour.  |
| Vat red B                      |  |  |
| Vat red B and Indigo           | Gradually<br>bluer, then<br>discharged |  |

As a rule, direct (substantive) dyeings, direct dyeings diazotised and developed, coupled with paranitraniline, after-treated with formaldehyde, metallic salts, etc., basic, Sulphur, Alizarin, and mordant dyeings on cotton give no coloration with the cold chloroform. They are further distinguished by boiling a small pattern with dilute titanous chloride.

All direct and after-treated direct dyeings are decolorised with the exception of the Thiobenzyl group (reduced to yellow); basic dyeings are discharged, leaving the fibre the yellowish-brown of titanium tannate; Sulphur dyeings evolve hydrogen sulphide gas (for this test reagent must be boiled just before use), whereas Alizarin dyeings are not as a rule decolorised, except in the case of mordant Azo dyestuffs, Alizarin yellow G, etc.

On boiling with water, direct dyeings bleed and the liquid becomes more or less highly coloured; developed or after-treated direct dyeings do not usually bleed off in boiling water or only slightly.

On the other hand, as a rule the Ice colours and many of the vat colours belonging to the Indigoid and Acridone classes are soluble in cold chloroform giving characteristic colorations, and with some vat dyeings a characteristic fluorescence.

The bleach solution test can be used to distinguish between the various Ice colours on the fibre, Azo pink BB being discharged to a bright yellow-orange, Chloranisidine red only being discharged slowly after a time, whereas *p*-nitro-*o*-anisidine on  $\beta$ -naphthol is not affected.

To distinguish between the various Primuline dyeings diazotised and developed with phenol, resorcin,  $\beta$ -naphthol, etc., and also after-treated with hypochlorite on the other hand, the dyeing is boiled with titanous chloride. Developed Primuline dyeings are reduced to bright yellow, which can be diazotised and developed with  $\beta$ -naphthol, to a red. On treatment with hypochlorite, Primuline is reduced to a brownish colour, and cannot be diazotised and developed to a red.

Some basic colours are not insoluble in chloroform; many give more or less deep colorations when not fully fixed. Brilliant green and Malachite green give coloured solutions even when fully fixed. Two other exceptions to the above general rule are Dianisidine blue and Alizarin blue, which are soluble in chloroform, giving violet and blue colorations respectively. Indigo and Ciba blue are soluble, and of the other vat dyes, Thioindigo red B, Indanthrene violets, Indanthrene dark blue BO give highly fluorescent solutions. To distinguish

between Indigo and Ciba blue the dyeing is spotted with strong nitric acid, and after a few seconds immersed in cold titanous chloride solution. Ciba blue undergoes very little alteration during these tests, whereas the Indigo dyeing gives a yellow spot with nitric acid, and the blue colour does not return on immersion in titanous chloride solution.

An extension of Holden's use of chloroform to other chlorhydrocarbons has been suggested by Gowing-Scopes. The dyestuffs to be separated are extracted with these solutions in the following order, being then further separated as suggested below :

A.—*Tetrachlorethylene extract*.—Evaporate and extract with pentachlorethane :

*Soluble*.—Leaf green, Rhodamine B extra, Sudan III.

Residue extracted with tetrachlorethane :

*Soluble*.—Nigrosine (sp. sol.) Victoria blue B.

*Insoluble*.—Ethyl green.

B.—*Pentachlorethane extract*.—Evaporate and extract with trichlorethylene :

*Soluble*.—Victoria blue BS, Spirit green II, Methyl violet B, Methyl violet B extra.

*Insoluble*.—Aniline blue II B.

C.—*Trichlorethylene extract*.—Evaporate and extract with tetrachlorethylene :

*Soluble*.—Aniline blue BB, Malachite green, Diamond green G, Diamond green B, Auramine OO, Eucrysine RR.

*Insoluble*.—Chrysoidine, Rosaniline, Metanil yellow extra.

D.—*Tetrachlorethane extract*.—Evaporate and extract with dichlorethylene :

*Soluble*.—Japan black, Jet black BT, Patent blue A, Neptune blue, Ruben N, Safranin scarlet B, Phenolphthalein.

*Insolubles*.—Safranin scarlet G

E.—*Dichlorethylene extract*.

*Soluble*.—Nigrosine G, Methylene blue, Vesuvine OOL, Spirit scarlet G, Induline scarlet, Bismarck brown.

*Insoluble*.—Nigrosine (water sol.), Methyl blue, Soluble blue IN, Nicholson's blue, Vesuvine BL, Eosine (yellowish), Eosine (bluish), Cotton scarlet, Indigo carmine, Methyl orange, Fluorescein.

### *Detection of Hydron blue.*

To distinguish Hydron blue from Indigo and Sulphur blue dyed materials, the following tests serve :

1. Hydron blue is not stripped from its dyeings by boiling organic solvents, chloroform, 100 per cent. formic acid, glacial acetic acid, etc., which dissolve Indigo from its dyeings.

2. A small piece of a Hydron blue dyeing immersed in cold concentrated sulphuric acid gives a grey rim in the acid after a short time. Sulphur blue dyeings give a fine violet rim as a rule.

3. Hydron blue and Sulphur blue dyeings evolve hydrogen sulphide on boiling with titanous chloride.

4. Hydron blue dyeings immersed in bleach solution of 5°Tw. remain unaltered ; Sulphur blue dyeings are discharged.

### *Black dyestuffs.*

The behaviour of one or two individual blacks on cotton are notable. On boiling cotton dyed with Logwood black with dilute hydrochloric acid the colour is stripped and the solution becomes reddish-orange in colour. Aniline black and Diphenyl black turn brown on boiling with titanous chloride, and are distinguished from Sulphur black by yielding practically no hydrogen sulphide in this test. To further distinguish between these blacks portions of original patterns are immersed in bleach solution of 5°Tw., and acetic acid gradually added. Sulphur blacks are decolorised, Ferrocyanide Aniline blacks give an olive to green fibre, other Aniline blacks and Diphenyl black become red-brown.

### *Mordant dyestuffs.*

To identify the mordant dyestuffs on the fibre, Holden also recommends immersion in bleach solution of 5°Tw., with addition of acetic acid. After allowing to stand, the liquid is poured off, and the material acidified with cold acetic acid and washed.

Mordant dyestuffs on aluminium mordant are decolorised. To confirm aluminium, the discharged pattern is boiled in a solution of logwood for a few seconds. With alumina mordant a violet-coloured fibre is obtained. Mordant colours dyed on iron mordant are discharged leaving a buff-coloured ground. To confirm iron, the discharged pattern is boiled in a solution of logwood for a few seconds ; with iron mordant a black-coloured fibre is obtained.

The reactions of the various vat dyes on the fibre have been investigated by A. G. Green (*J. Soc. Dyers and Col.*, 1910, p. 83).

The following tests serve for the detection of these dyestuffs on the fibre :

1. Coloration with concentrated sulphuric acid.
2. Reaction of the dyeing with bleach solution of 5°Tw., whether discharged or otherwise altered in shade.
3. Reaction of the dyeing on spotting with concentrated nitric acid and subsequent immersion in titanous chloride solution.
4. Reduction with warm alkaline hydrosulphite solution.
5. Effect of heating with small quantities of the following solvents : Benzene, pyridine, 100 per cent. formic acid, glacial acetic acid, cresol, etc.

Of these tests only (1) and a modification of (4) in which an acidified Rongalite solution is employed, have been used by Green in his tables.

Acid, basic and substantive colours (the latter not developed or after-treated) can be stripped from their dyeings on the vegetable fibres, the acid colours by warming with water alone, basic colours by boiling with alcohol acidified with a few drops of hydrochloric or formic acid, and substantive colours by boiling with water or dilute ammonia. These solutions may then be concentrated to small bulk and the dyestuffs identified according to Weingärtner's scheme as described in Section A.

## 2. Dyeings on Animal Fibres.

Basic dyeings may be stripped by boiling with alcohol acidified with a few drops of hydrochloric or formic acid, acid and substantive dyeings may be stripped by boiling with dilute ammonia. These extracts can then be concentrated to small volume and examined according to Weingärtner's scheme.

Alizarin, mordant, and after-chrome dyeings cannot be stripped in this way, but can be identified by using the tables of reactions of dyestuffs on the fibre referred to later

### Indigo on Vegetable and Animal Fibres.

A pure Indigo dyeing is not stripped by boiling with water, alcohol acidified with a few drops of hydrochloric or formic acid, or by boiling dilute ammonia. Hence any acid, basic, or substantive dyes used for bottoming or topping vat Indigo dyeings can be removed by these stripping liquids, and the extracts examined separately. Alizarin, mordant, and after-chrome colours dyed in conjunction with vat indigo on wool cannot be stripped, but the Indigo may be completely removed by extraction with boiling pyridine or cresol as recommended by A. G. Green ("Estimation of Indigo, etc.," *J. Soc. Dyers and Col.*, 1913, p. 229), leaving the ground colour undissolved in most cases. This latter can then be identified by its reactions on the fibre. Direct dyestuffs are only partially stripped by boiling water or dilute ammonia.

Indigo dyeings when spotted with concentrated nitric acid yield the well-known yellow spot, which, however, is also given by many other dyestuffs.

By warming with alkaline hydrosulphite solution, Indigo is reduced to the yellow soluble leuco-compound (salt of Indigo-white), and stripped from the fibre.

By cautious heating in a glass tube, medium and full dyeings on cotton of Indigo and halogenated derivatives of Indigo, such as the Ciba blues, yield very characteristic violet vapours.

All Indigo dyeings are stripped when extracted with boiling pyridine. On mixing the extract with water the Indigo is precipitated and may be filtered off, washed, dried, and submitted to the sublimation test, above described, for confirmation.

According to a scheme for the Identification of Colouring Matters on Vegetable and Animal Fibres of A. G. Green (*J. Soc. Dyers and Col.*, 1905, p. 237; 1907, p. 252), which is an adaptation of his modification of Weingärtner's method for the identification of dyestuffs in substance, the chemical class and dyeing relationship of the dyestuffs present are first determined, when in many cases the actual dyestuff can be identified by use of tables of reactions of colouring matters on the fibre. Green's scheme is, in the first instance, only applicable to the determination of the class of dyestuff present, but in many instances this is sufficient to enable the dyestuff to be at once identified.

Tables of reactions of dyestuffs on the fibre have been compiled by various chemists, the most complete perhaps being those of C. Dreher, later amplified by G. Weber, O. Knecht, and W. Dürsteler. These are to be found *in extenso* in Lunge's "Technical Methods of Chemical Analysis," Vol. II., Part II) (English translation and adaptation by Keane). Representative tables are also included in Heermann's book, "Koloristische und textilchemische Untersuchungen." These two sets of tables will serve for the identification of a large number of dyestuffs, but are incomplete and do not include a large number of the newer fast substantive, acid, and after-chrome dyestuffs of great importance; also only the early vat dyestuffs are included.



# PHYSIOLOGICAL CHEMISTRY.

## Examination of Urine.

The physical and chemical characters of urine are, in very many cases, of great importance in making a diagnosis, and their variation furnishes an important guide to the progress of disease. Often only a qualitative examination for glucose is required, and usually information concerning not more than two or three constituents is sufficient. Human urine, even during health is of extremely complex composition, and normally contains :

1. *Inorganic compounds.* Sodium and potassium chlorides; potassium sulphate; sodium, calcium and magnesium phosphates; silicic acid; calcium carbonate; ammonium salts.

2. *Organic compounds.* Urea, uric acid, xanthine, hypoxanthine, creatinine, pigments, ferments (pepsin, trypsin), fatty acids, oxalic, oxaluric, lactic, succinic, glycerophosphoric, thiocyanic, and hippuric acids, aromatic and ethereal sulphates.

3. *Gases.* Nitrogen and carbon dioxide.

Pathological urine in addition to the above may contain : albumin and other proteids, hæmoglobin, methæmoglobin, bile pigments, bile acids, acetone, acetoacetic ether, hydroxybutyric acid, lucine and tyrosine, dextrose, lactose, fats, cystin; various sediments; organised bodies as blood corpuscles, urinary casts and renal epithelium. There may also be present colouring, odorous and other substances, the result of taking medicines.

The quantity of urine secreted daily by a healthy man is on an average  $1\frac{1}{2}$  litres of Sp. Gr. 1·015 to 1·025. The composition varies considerably according to diet and exercise. According to Vogel the average is :

|                  |     |     |        |                   |     |      |
|------------------|-----|-----|--------|-------------------|-----|------|
| Water            | ... | ... | 1440·0 | Phosphoric acid   | ... | 3·0  |
| Insoluble matter | ... | ... | 60·0   | Sulphuric acid    | ... | 2·0  |
| Urea             | ... | ... | 35·0   | Earthy phosphates | ... | 1·2  |
| Uric acid        | ... | ... | 0·75   | Ammonia           | ... | 0·65 |
| Sodium chloride  | ... | ... | 16·5   | Free acid         | ... | 3·0  |

For examination, a sample of the mixed urine passed in twenty-four hours should be taken, but in case this is not available that passed three hours after a meal may be used, the analysis being conducted without delay, as changes take place due to fermentation.



## Physical Examination.

*Quantity.* The amounts of urine passed during the day and night should be noted separately. The total in a state of health averages about 1,500 cc.

*Colour.* Normal urine is of an amber colour, the colouring matters being urochrome and urobilin. Acid urine is darker than alkaline. It is usually deeper in colour when the amount secreted is lessened and paler when the amount is excessive. A reddish or orange-brown tint may indicate blood, bile or the use of such drugs as rhubarb or senna. Greenish or greenish-black urine may be due to the presence of bile or to the use of such drugs as phenol. A yellowish tint may be caused by bile, pus or fat. The urine may appear blue in typhus or from methylene blue, and may be opalescent from bacilli or suspended matter.

*Consistence.* Normal urine is a thin aqueous fluid. Bile and sugar make it less mobile, pus gives it a ropy appearance, whilst fibrin causes it to gelatinise.

*Odour.* Normal urine has an aromatic odour. The presence of ethyl acetoacetate imparts a fruity odour. The administration of turpentine confers a violet-like odour, sandal wood oil and copaiba impart their characteristic odours. Fermented urine is ammoniacal.

*Deposit.* Normal urine on standing shows a cloud of mucus usually settling to the bottom. It may also contain (1) deposits of free uric acid and urates which are usually reddish or dark brown ("cayenne pepper" and "brick dust") and dissolve on heating; (2) phosphates (Ca and Mg) which are colourless, flocculent, insoluble on heating, soluble in dilute acids; (3) oxalates, a small deposit insoluble in dilute acids.

*Specific Gravity.* This may be determined by any of the usual methods. Small hydrometers (urinometers) are made graduated from 1·000 to 1·050, but the graduations for sugar on such should be ignored as the gravity may vary independently of the sugar content. If the temperature is above or below 15°C. the gravity can be deduced by adding 0·0015 to the observed gravity for every degree above 15°C. or subtracting 0·0015 for every degree below 15°C.

*Solids.* The approximate weight of solids per litre is calculated by doubling the last two of the three decimals denoting specific gravity. Thus urine of Sp. Gr. 1·020 corresponds to 40 grm. per litre (= 4%). The percentage multiplied by 4·375 gives the grains per fluid ounce, in this case 17·5.

## Chemical Examination.

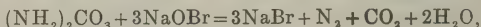
The urine is tested with litmus paper. Normal urine is usually faintly acid, but may be alkaline after meals. On standing for some time ammoniacal fermentation takes place, and it becomes strongly alkaline. Alkaline urine is passed in certain pathological conditions of the urinary tract, and strongly acid urine may be passed in febrile diseases, especially acute rheumatism, and after taking certain drugs, such as sodium dihydrogen phosphate.

*Estimation of solids.* 100 cc. are evaporated in a platinum basin until constant in weight and the residue weighed. Decomposition of the syrupy residue leads to inaccurate results. The solids are from 4.6 to 6.5 per cent.

*Ash.* 100 cc. is evaporated in a platinum crucible, the residue ignited to carbonise organic matter, extracted with hot water and filtered. The residue and filter are dried and ignited, then the filtrate is added, evaporated to dryness, ignited and the crucible weighed. The ash is 0.5 to 0.6 per cent.

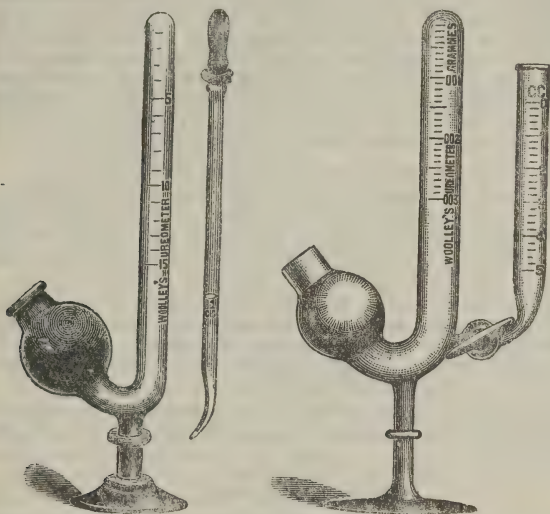
## Urea, $\text{NH}_2\text{CO.NH}_2$ .

The usual method of estimating urea, Hüfner's, is to decompose it and measure the nitrogen evolved. The reagent employed is sodium hypobromite solution prepared as required by adding 1 cc. of bromine to 9 cc. of caustic soda solution (0.4 gm. per cc.). A brine charged nitrometer is a convenient apparatus, and the determination is made by introducing 5 cc. of urine, 10 cc. of hypobromite solution, and 10 cc. of water. Nitrogen is at once evolved (see "Nitrometer," Vol. I):



and may be measured as soon as the reaction is completed, the  $\text{CO}_2$  being retained by caustic soda. Theoretically 1 cc. of nitrogen at N.T.P. = 0.0027 gm. urea, but in practice only 92 per cent. of the nitrogen is evolved, but it has been found that the increase in volume of the gas due to room temperature (taken as  $18^\circ\text{C}.$ ) and the vapour tension, almost exactly compensate the loss, and therefore 1 cc. of  $\text{N} = 0.0027$  gm. urea under laboratory conditions. If much sugar be present, or if a little glucose be added, the whole of the nitrogen is evolved; in which case it is usual to deduct 8 per cent. from the volume shown, and take the remainder as 1 cc.  $\text{N} = 0.0027$  gm. urea as before. Various forms of ureometers for estimating

urea have been devised with a view to convenience and portability. The "Doremus" and "Victoria" are perhaps the best known.



"Doremus."

"Victoria."

### *Uric acid, $C_5H_4N_4O_3$ .*

Uric acid occurs normally in urine to the extent of 0.7 per cent., but in pathological urine it is often met with as a sediment, and the crystals may then be recognised under the microscope (see "Sediments").

#### *Tests for Uric acid.*

Urine acidified with hydrochloric acid and allowed to stand in a cool place deposits crystals of uric acid; these may be identified by examination under the microscope and the murexide test.

*Murexide test.* The crystals are placed in a porcelain basin, a drop of nitric acid or a little chlorine water added, and the solution evaporated to dryness on a water-bath. A yellow residue coloured purple-red by dilute ammonia indicates the presence of uric acid.

### *Estimation of Uric acid.*

1. *Hopkins method.* To 100 cc. of the urine enough ammonium chloride is added to make a saturated solution (about 30 grm.), and the mixture is set aside for two hours, stirring occasionally, when uric acid is precipitated as acid ammonium urate. This is filtered off, washed with saturated solution of ammonium sulphate and transferred to 100 cc. of water; 20 cc. of strong sulphuric acid are added, and the liquid, while still hot (about 60°C.), is titrated with N/20 permanganate until the pink colour persists for two or three seconds.

1 cc. of N/20 permanganate = 0.00375 uric acid.

2. *Gowland-Hopkins method.* The uric acid, precipitated as acid ammonium urate as before, is decomposed with hydrochloric acid, allowed to stand for two hours, and the precipitated uric acid dissolved in sodium carbonate and titrated as before. (See *P.J.* i/99, 266.)

3. *Gravimetric.* The acid ammonium urate is decomposed with hydrochloric acid as before; the uric acid is collected, washed with water, then alcohol, dried and weighed. To the weight found 0.001 grm. is added for every cc. of mother-liquor (not including the washings).

4. The hypobromite method ("Gas Analysis," Vol. I) may be used for decomposing the acid ammonium urate. (*L.* i/07, 14; *L.* ii/03, 77.)

### *Glucose (Dextrose).*

Normal urine contains small quantities (about 0.25 per cent.) of glucose, but in certain pathological conditions this amount is considerably increased. In *diabetes mellitus* the continued presence of considerable quantities of this sugar is characteristic, and consequently the Sp. Gr. is higher than normal, usually between 1.030 and 1.040, even though the amount of urine passed is greatly increased. In twenty-four hours the volume may be 3000 to 4000 cc. containing 10 to 100 grms. of glucose.

*Tests.* 1. Fehling's solution is reduced by diabetic urine on boiling. Acetone, lactose, and aldehydes may also be present, and have a similar reaction. This test has been modified by Allen (*Analyst.* xix, 178; *P.J.* ii/95, 307), who adds the copper solution whilst boiling, cools, adds sodium acetate and filters to remove uric acid, phosphates and xanthine. The alkali is now added and again boiled, when cuprous oxide is precipitated before boiling if above 0.25 per cent. be present, or on cooling if less than this proportion.

2. Johnson's or Braun's picric acid test. A saturated cold aqueous solution of picric acid is mixed with an equal volume of normal caustic soda and boiled; a measured quantity of urine is then added, and the mixture again boiled. A deep red colour, due to reduction of the picric to picramic acid, is produced, the depth of colour being proportional to the amount of glucose present. This reaction has been made quantitative by the aid of the "picro-saccharometer," which gives a standard tint. Creatinine, which gives a similar colour, must be removed by treatment with mercuric acetate followed by zinc before applying this test.

3. Phenylhydrazine test. Half a test-tubeful of urine is mixed with 0.5 grm. of phenylhydrazine and 1 cc. of glacial acetic acid, placed in a beaker of boiling water for about half an hour, with occasional shaking, and then allowed to cool. The sugar is then separated as an osazone, and should be further examined under the microscope and the melting point determined. Phenylglucosazone is in yellow acicular crystals, melting at  $205^{\circ}$ . Lactose occasionally found in the urine of nursing women yields phenyl lactosazone which forms short and broad crystals melting at  $200^{\circ}$ . Glycuronic acid forms a similar compound, melting at  $150^{\circ}$ .

4. Indigo or Nitropropiol test. The urine is diluted and mixed with an equal volume of nitropropiol solution (sodium *o*-nitrophenylpropionate); on boiling, a blue colour, due to formation of Indigo, is produced, immediately or in a few minutes, according to the amount of glucose.

5. Nylander's Test (modified). A solution of bismuth tartrate (1 per cent.) in caustic soda (8 per cent.) is prepared and warmed with an equal volume of urine. If glucose be present a black precipitate of bismuth suboxide is formed, but lactose and albumen also give positive results. Albumen should be removed by boiling and filtering before applying the test. Lactose may be distinguished by the fermentation test (6). This modified Nylander's test will detect 0.1 per cent. of glucose.

6. Fermentation test. The urine, if necessary, should be slightly acidified with citric acid and then boiled to expel air. The urine is then shaken up with some fresh, active yeast in a special fermentation tube or in an ordinary test-tube, which is inverted in a bath of mercury, carefully excluding air bubbles. After standing a few hours in a warm place a bubble of carbon dioxide collects at the top of the tube if glucose be present. Lævulose, which also reduces Fehling's solution, ferments with yeast, and forms an osazone, is

occasionally found alone in urine, but more commonly with dextrose. The polarimeter will distinguish between levulose and dextrose. The fermentation test may be modified thus: two flasks of 100 cc. capacity are filled with urine. To one, a piece of crumbled yeast is added, whilst the other is tightly corked. The two tests are allowed to stand for 24 hours in a warm place, when, if glucose be present, carbon dioxide will be evolved by the one containing yeast and may be identified by passing into lime water. The Sp. Gr. of each is then determined, when if over 0.5 per cent. of glucose be present the gravity will be perceptibly lower after fermentation. Each degree of density lost is approximately equivalent to 1 grain of glucose per ounce (0.23 per cent.) (L. ii/06, 1136.)

7. *Optical activity.* Colouring matter and other substances are removed by boiling with lead acetate or mercuric acetate, as described below. The colourless filtrate is then examined with the polarimeter; glucose, if present, will give a dextro rotation; the percentage of glucose may be found by the usual calculation from the observed rotation ( $[\alpha]_D = +52.7$ ).

The presence of glucose must not be assumed unless the urine gives positive reactions with several of the preceding tests. Formaldehyde, which also reduces Fehling's solution, occurs in urine after the administration of such drugs as hexamethylenetetramine ("urotropin"), and it may be tested for thus: to 5 or 10 cc. of sample add 5 drops of 1 per cent. aqueous solution of phloroglucinol followed by 5 drops of 30 per cent. caustic soda solution. A red colour indicates formaldehyde sensitive to 1 in 2,000,000 water and 1 in 50,000 urine, but no colour is given with hexamethylenetetramine.

*Estimation.* 1. The usual method is that of Fehling, which in ordinary cases gives satisfactory results. Uric acid, creatinine and glycuronic acid must first be removed by boiling the urine with 5 per cent. of its volume of saturated solution of sodium acetate and 25 per cent. of saturated solution of mercuric chloride, filtering out the precipitate and removing the excess of mercury by boiling with zinc dust and filtering. It is usual to place 10 cc. of standard Fehling's solution in a porcelain basin with 40 cc. of water, and to heat the mixture to boiling. Urine from a burette is then run in until the blue colour is just discharged. The presence of the cuprous oxide masks to some extent the end-point, and to obviate this several modifications have been introduced, the chief of which are Pavy's and Gerrard's.

2. *Pavy's Method.* The standard solution is prepared



by mixing 10 cc. of Fehling's solution with 30 cc. of strong ammonia (0.888) and 10 cc. of 10 per cent. caustic soda solution, and diluting to 100 cc.; the oxidising power of this solution is one-tenth that of Fehling's. As the reduced Pavy's solution is very rapidly reoxidised, air must be excluded during the titration. This is accomplished by conducting the titration in a flask fitted with a three-hole cork; through one hole passes a tube connected with the nozzle of the burette, while the others provide entrance and exit for a stream of coal-gas or hydrogen. A better method is to cover the surface of the liquid with melted paraffin and allow the nozzle of the burette to dip below the surface. The titration is conducted in the same way as before, but as the cuprous oxide is dissolved by the ammonia the end-point is shown by the discharge of the blue colour. A few pieces of porous pot added will prevent "bumping" during boiling.

3. Gerrard's Method. A solution is prepared by decolorising 100 cc. of boiling Fehling's solution with a 5 per cent. solution of potassium cyanide and making the volume up to 500 cc. For use 50 cc. of this solution are mixed with 10 cc. of Fehling's solution, and the urine run in whilst boiling, in the same way as before, the end-point being the discharge of the blue colour. Only the second quantity (10 cc.) of Fehling's solution is reduced by the glucose in the urine. This method is recommended.

### *Albumin.*

Several proteins may occur in urine, but only mucin occurs in normal urine. Serum-albumin and serum-globulin are both included in the term "albumin," and their presence in urine is termed "albuminuria," a condition appearing in acute *parenchymatous nephritis* or Bright's disease.

*Tests.* The urine is first clarified by filtration, through barium carbonate if necessary, and if alkaline it is made slightly acid with dilute acetic acid.

1. Heat test. The urine is boiled for about a minute; albumin, if present, is precipitated as white flocculi gradually sinking to the bottom on standing. Nitric acid is added when precipitated phosphates will be redissolved.

2. Nitric acid test. The urine is carefully poured on to the surface of an equal volume of concentrated nitric acid. If albumin is present, it is coagulated and forms a white ring on the surface of the nitric acid; small amounts may not appear until after some minutes. Uric acid, urea and resins may also be precipitated, but the first two are soluble on warming, the last in alcohol. Other substances give similar rings. (L. ii/06, 1459.)



3. **Ferrocyanide test.** The urine is acidified with acetic acid, and a 10 per cent. solution of potassium ferrocyanide added; a white precipitate indicates albumin; traces are also precipitated after a short interval.

4. **Salicylsulphonic acid test.** A few crystals of the acid, or a small quantity of solution, added to urine, gives a precipitate or turbidity if albumin is present, and, like the next test, does not cause precipitation of the mucin.

5. **Trichloroacetic acid test.** A saturated solution of the acid is carefully poured on to the surface of the urine, when albumin, if present, appears as a white cloud at the junction of the liquids. Alkaloids, which may also be precipitated, redissolve on heating or adding excess of reagent.

*Estimation.* A simple and convenient method, at the same time a fairly accurate one, is that of Esbach. The urine must be diluted if of Sp. Gr. 1.010 or more and the degree of dilution noted for calculation. The Esbach albuminometer, consisting of a thick glass graduated tube closed by a rubber stopper, is filled up to the mark *U* with the diluted urine and then to the mark *R* with the reagent, made by dissolving 10 grm. picric acid and 20 grm. citric acid in a litre of water. After mixing the albuminometer is allowed to stand for exactly 24 hours at a temperature of 15° to 20°C. and the volume of the precipitate read off. The graduations indicate grams per litre in the diluted urine. For accurate determination, the albumin is precipitated by a nitrogen-free reagent, *e.g.* tannic acid, and the nitrogen in the washed precipitate estimated by Kjeldahl's method. The amount of nitrogen multiplied by 6.3 gives the amount of protein.



#### *Albumoses and Peptones.*

Albumose is readily detected by first removing the albumin by boiling and filtering, and then adding a saturated solution of salicylsulphonic acid to the clear filtrate; a precipitate indicates the presence of albumoses.

For peptones the albumin is removed as before, and the filtrate is saturated with ammonium sulphate and again filtered. To this filtrate a dilute solution of salicylsulphonic acid is added when a precipitate soluble on warming and reappearing on cooling indicates peptones.

### *Acetone bodies.*

Acetone bodies include acetone,  $\beta$ -hydroxybutyric acid and acetoacetic acid.

Acetone occurs in febrile diseases and cancer and can often be detected by the odour of the urine; in such cases the Sp. Gr. will be considerably decreased. The urine is usually distilled, using a Liebig's condenser, and the first portion of the distillate used for the tests.

*Legal's test.* Fresh concentrated sodium nitroprusside solution added to the distillate, made slightly alkaline with caustic potash, produces a red colour in presence of acetone, rapidly fading to yellow, which become reddish-violet, then blue on addition of acetic acid.

*Lieben's test.* To the distillate, made strongly alkaline with caustic potash, add a little iodine solution and allow to stand. Iodoform is precipitated in the presence of acetone; the crystals can be confirmed microscopically and by their odour.

Acetoacetic acid. *Gerhardt's test.* Ferric chloride gives a red coloration discharged by potassium citrate. Salicylic acid and its compounds produce similar colorations, but acetoacetic acid may be removed by boiling for five minutes, and any reaction then will be due to salicylic acid.

$\beta$ -Hydroxybutyric acid is found only when acetoacetic acid is present also. It may be tested for by the polarimeter, when sugar has been removed by fermentation; its specific rotation is  $[\alpha] = -23.4^\circ$ .

### *Hippuric Acid.*

Hippuric acid occurs in normal urine to a very small extent, but in the urine of herbivora it is the chief nitrogenous product. Benzoic acid, taken as medicine, is excreted as hippuric acid.

*Estimation.* A litre of the urine made slightly alkaline with sodium carbonate is filtered and evaporated nearly to dryness. The residue is extracted with absolute alcohol, the alcohol evaporated and the residue acidified with hydrochloric acid. The acid solution is now repeatedly extracted with ethyl acetate, the filtrates united, washed with water, and allowed to evaporate, when hippuric acid crystallises out. This is dried over sulphuric acid and weighed. Fat, if present, may be removed by washing the hippuric acid with petroleum ether.

### *Creatinine.*

This product occurs normally in urine to the extent of 0.2 per cent., and is readily soluble in water.

*Test.* The addition of a few drops of sodium nitroprusside solution followed by dilute caustic soda to urine produces a burgundy red colour which fades on boiling, but on the addition of a little acetic acid to the boiling solution, Prussian blue is produced.

#### *Determination in Urine.*

Folin has adapted the Jaffé colour reaction of creatinine with picric acid and caustic soda to its estimation. A layer of  $N/2$   $K_2Cr_2O_7$  solution 8 mm. deep has the same colour as a layer 8.1 mm. deep of a solution prepared from 10 mgm. of pure creatinine, picric acid and caustic soda. The colour of the unknown solution is compared with that of  $K_2Cr_2O_7$  solution in a Duboscq colorimeter, and the creatinine calculated, as the colours are directly proportional.

Into a 500 cc. flask are placed 10 cc. of urine, 15 cc. of saturated picric acid solution (12 grm. per litre), and 5 cc. of 10 per cent. caustic soda solution. After standing for at least 5 minutes, the liquid is diluted to 500 cc. with water, and the colour compared with that of  $N/2$  dichromate. The dichromate is placed in one cup of the colorimeter and the depth through which the colour is viewed adjusted to 8 mm. by means of the screw and vernier. The tint solution is placed in the other cup, and this side is adjusted with the screw until the colours appear identical.

*Example:* 10.1 mm. of the solution = 8 mm. dichromate = 8.1 mm. of a solution containing 10 mgm. of creatinine per 500 cc.

$$\text{Creatinine in 10 cc. of urine} = 10 \times \frac{8.1}{10.1} = 8.02 \text{ mgm.}$$

### *Indican.*

*Ehrlich's test.* 0.33 grm. of dimethylaminobenzaldehyde is dissolved in 50 cc. of water and 55 cc. of strong hydrochloric acid added. The urine is boiled with an equal volume of this solution, cooled and made alkaline with ammonia; a red colour indicates indican (for estimation see sulphates).

### *Indoxyl.*

An equal volume of hydrochloric acid is added, the liquid shaken, and a drop or two of sodium hypochlorite solution added; a blue colour, extracted by chloroform, indicates indoxyl.

### *Sodium Chloride.*

This is estimated in the usual manner by standard silver nitrate; 10 cc. of urine is diluted to 200 cc. with water and titrated with N/10 silver nitrate, using potassium chromate as indicator. 1 cc. N/10  $\text{AgNO}_3$  = 0.00585 grm. NaCl.

### *Phosphates.*

Phosphoric acid occurs in the urine in combination with an alkali or alkaline earth metal; a small amount of phosphorus is in organic combination. Alkaline earth phosphates are precipitated when the urine becomes alkaline through ammoniacal fermentation. Acid sodium phosphate appears in the urine after oral administration, and such urine being acid the earthy phosphates remain in solution. Phosphoric acid is estimated by means of standard solution of uranium nitrate. 50 cc. of urine is made acid with acetic acid and a little sodium acetate (about 1 grm.) added. The mixture is now heated to nearly boiling and the standard uranium solution run in until a drop of the mixture gives a brown coloration with a drop of fresh solution of potassium ferrocyanide. The uranium solution is standardised against a standard solution of sodium phosphate containing the same proportions of acetic acid and sodium acetate. Normal urine contains 0.15 to 0.2%  $\text{P}_2\text{O}_5$ .

### *Sulphates.*

Total sulphuric acid is estimated gravimetrically by precipitating as barium sulphate. 100 cc. of urine, with the addition of 10 cc. of hydrochloric acid, is boiled with a solution of barium chloride; the precipitated sulphate is filtered off, washed, dried, ignited and weighed, and from the weight the amount of total sulphuric acid is calculated.

Ethereal sulphates are estimated by Salkowski's method thus: To 100 cc. of urine an equal volume of solution, containing two parts of saturated solution baryta and one part saturated solution barium chloride, is added, and the mixture is allowed to stand. The precipitate is filtered out, 100 cc. of the filtrate taken (= 50 cc. urine), and hydrochloric acid added in large excess. The mixture is now heated to  $100^\circ$ , and the precipitate collected and weighed, and from the weight the amount of ethereal sulphates is calculated. This amount subtracted from total sulphuric acid gives the sulphuric acid.

### *Acidity and Alkalinity.*

Acidity, due mostly to the presence of acid sodium phosphate, is determined by decinormal alkali, using phenolphthalein as indicator. Each cc. of standard solution

= 0.012 grm. acid sodium phosphate. Acidity is usually reported in terms of the number of cc. of this alkali required for 10 cc. urine, *e.g.* 3 cc. = 3°.

Alkalinity is estimated and reported in a similar manner using standard acid.

### *Ammonia.*

Ammonia is present in normal urine to the extent of 0.30 per cent. by weight. It is estimated by placing 50 cc. of fresh urine, or urine preserved with phenol, in a shallow vessel, adding 20 cc. milk of lime, and placing it under an air-tight bell-jar along with a second dish containing 10 cc. of normal sulphuric acid. After standing for three days the acid is titrated.

A better method is to distil off the ammonia under reduced pressure, when the risk of decomposing the urea is obviated. Malfatti's method utilises condensation of ammonia with formaldehyde. (See *B.M.J.*, i/09, 715.)

### *Bile Pigments.*

Urine containing bile has generally a greenish-yellow colour, and the froth a yellow colour. This occurs in jaundice.

Gmelin's test. A little fuming nitric acid is placed in a test-tube and an equal volume of the urine carefully poured on to the surface. If bile pigments are present a green ring appears at the zone of contact, and below this appear in order, violet, red, and yellow zones. The latter without the green zone do not indicate bile.

Fleischl's modification. The urine is mixed with a strong solution of sodium nitrate and then strong sulphuric acid is carefully added when coloured zones are produced as before. Traces may be detected by adding lime water and passing carbon dioxide through it until the excess of lime is precipitated. The precipitate is collected and treated with fuming nitric acid, when colours as before will be observed.

### *Other Colouring Matters.*

Ehrlich's Diazo reaction. In several pathological conditions some aromatic substance is present which gives a red colour on the addition of diazobenzene sulphonic acid. The test is applied thus: To 5 cc. of urine an equal volume of  $\frac{1}{2}$  per cent. solution of sulphanilic acid in 5 per cent. hydrochloric acid is added, then a few drops of  $\frac{1}{2}$  per cent. sodium nitrite solution; the mixture is shaken and then made strongly alkaline with ammonia. A positive result is indicated if after shaking the liquid assumes a port wine colour and the froth

is red. Urine passed in cases of tuberculosis, typhoid and measles usually gives this reaction.

*Vegetable Colours.* After taking drugs containing emodin or chrysophanic acid the urine becomes highly coloured, the colour becoming lighter with acid and deeper with alkalis. Santonin gives similar reactions, but the colour may be extracted with amyl alcohol.

*Phenols.* Resorcinol, hydroquinone, or phenol may occasionally be present. Such urine becomes dark-coloured on exposure to air.

## Examination of Urinary Sediments.

Normal urine, which is at first clear, often throws down a deposit of urates on cooling, and on becoming alkaline through standing, a precipitate of phosphates. Pathological urine may be cloudy at first, and the sediment is then of importance. The urine is allowed to stand for about twenty-four hours in a conical glass vessel. In hot weather a preservative should be added, preferably one-fourth the volume of a saturated aqueous solution of chloroform, to prevent ammoniacal fermentation; but a much better method is to centrifuge, when the sediment will collect in a few minutes. A drop of the liquid from the bottom of the settling vessel is transferred by a pipette to a glass slide and covered with a thin cover-glass. It is then examined under the microscope, using first a low-power and then a high-power objective.

*Blood.* The presence of blood often imparts a characteristic dark coloration to the urine. Under the microscope the blood corpuscles may be recognised by their appearance. They are biconcave, having an average diameter of 0.0075 mm. ( $=7.5\mu$  or  $1/3386$  inch), but on standing they swell up, lose their shape and become disintegrated, which soon happens if the urine be alkaline. In acid urine they retain their shape for a longer period. Their colour furnishes some clue to their source, bright red blood suggesting a lesion near the point of discharge, paler washed-out corpuscles from a point higher up, from the pelvis or even the kidneys.

Confirmation of the presence of blood may be obtained by evaporating a small amount of the deposit to dryness with a fragment of sodium chloride at a low temperature. The residue is treated with a few drops of glacial acetic acid and heated on a slide. When cool, rhomboidal plates of hæmin may be found if blood is present.

*Heller's Test.* The urine is heated with strong caustic



potash or soda solution. The presence of blood is indicated by the production of a bottle-green colour, and by the precipitation of phosphates coloured brownish-red by blood.

*Pus and Mucus.* These occur as white corpuscles somewhat larger than red blood corpuscles, spherical in shape and varying much in size. They often present one or more nuclei which are made more distinct by addition of a drop of dilute acetic acid. A drop of acetic acid is placed on one edge of the cover-glass and a piece of filter-paper applied to the opposite side when the acid will flow underneath. Earthy phosphates are dissolved by acetic acid. A small amount of mucus is present in normal urine, but pus is discharged from suppurating surfaces and urine containing it will give the reactions for albumin. If much pus is present the urine will be viscid, and the sediment, on mixing with an equal volume of strong caustic potash solution, will form a thick viscid mass resembling white of egg.

*Epithelium cells.* These are much larger than corpuscles, and may be of almost any shape. They have ordinarily a well-defined nucleus, and are often united in groups of three or four.

*Casts.* These are casts of the uriniferous tubules of the kidney, and usually have a greater length than width; several different kinds occur, and experience alone will enable them to be satisfactorily identified.

*Spermatozoa.* The source of these bodies is the semen, and usually their presence has no pathological significance. They have a length of 0.050 mm., and appear as colourless rounded bodies with a long flagellum with which they are propelled rapidly forward, but as usually seen they are motionless.

Bacteria, parasites, fungi and fragments of tissue are met with, but these can only be identified by bacteriological methods.

*Crystals.\** These may consist of uric acid, urates, leucin, tyrosin, cystin, hippuric acid, calcium carbonate, sulphate or oxalate and earthy phosphates. Most of these have characteristic shapes, and may be recognised by their shapes and behaviour with reagents.

Uric acid crystals are relatively large, frequently visible to the naked eye, the commonest form being rosettes. They may dissolve on heating, and are soluble in alkali.

\* Illustrations of urinary sediments will be found in: Long's "Text-book of Urine Analysis," Allen's "Chemistry of Urine," etc.



Urates occur in a great variety of forms, usually in very small crystals. These are little changed by acids, whereas phosphates which are similar in appearance dissolve on addition of acid.

Cystin and cholesterin occur in large thin plates; the former are hexagonal and dissolve in ammonia.

*Fat globules*, which may come from several extraneous sources, as from a catheter, may be recognised by their appearance.

*Foreign matter.* A urinary sediment often contains foreign substances which may have become mixed with it accidentally after being voided. The most common of these are hairs, woollen, cotton or silk fibres, starch granules, pieces of vegetable tissue and remains of articles of food.

## Urinary Calculi.

Calculi are formed by the deposit of concentric layers of crystallised or amorphous substances on some nucleus, frequently on uric acid. Occasionally they consist of a single substance, such as calcium oxalate or cystin, but usually phosphates, calcium, and uric acid are present.

The calculus may be divided into half and its nucleus recognised. It is then crushed to powder and heated to bright redness on platinum foil; uric acid, ammonium urate and cystin are entirely consumed.

Uric acid is insoluble in water; soluble in caustic potash without evolution of ammonia; soluble with effervescence in nitric acid, the residue on evaporating being red and giving the murexide reaction.

Ammonium urate is soluble in hot water; soluble in caustic potash with evolution of ammonia; dissolves in nitric acid and behaves like uric acid.

Cystin is insoluble in water; soluble in ammonia, the solution depositing the characteristic hexagonal plates on evaporating spontaneously. Ignited with potassium nitrate and sodium carbonate the residue gives the usual reactions for sulphates.

If the calculus leaves a residue after ignition it may be calcium oxalate or calcium and magnesium phosphates.

Calcium oxalate (mulberry calculus) is insoluble in acetic acid, but soluble in hydrochloric acid. The residue after ignition at a low red heat consists of calcium carbonate, and dissolves in hydrochloric acid with effervescence.

The calcium and magnesium phosphates may be identified by the usual tests.

## Examination of Blood.

Blood consists of an aqueous fluid, blood plasma, holding in suspension innumerable corpuscles. It contains about 70 per cent. water, is alkaline in reaction, and has Sp. Gr. 1.053 to 1.066. The red colour of blood is due to a pigment in the red corpuscles, hæmoglobin which is a proteid coagulating at about  $54^{\circ}$ , is optically dextrorotatory, and contains about 0.5 per cent. of iron. It forms a loose compound with oxygen, oxyhæmoglobin, which gives the bright red colour to arterial blood.

*Red blood corpuscles.* These have an average diameter of 0.0075 mm. ( $7.5\mu$ ) and are discoid in shape with indentations in the two sides. One cubic millimetre contains normally 5,000,000 to 6,000,000 red corpuscles in the case of a man, and about 4,500,000 in the case of a woman. The number is determined by a hæmacytometer, the one commonly used being a Thoma-Zeiss. The blood is diluted by means of special pipettes to 1 in 100 or 1 in 200, and transferred to a microscopic slide having a cell 0.1 mm. deep, and divided into 16 squares, each square being again divided into 16 smaller squares which are  $1/20$  mm. square. The number of corpuscles in several smaller squares is counted and the average taken.

$$\text{Average} \times 4000 \times \text{dilution} = \text{no. per c.mm.}$$

Many other forms are made and are used in a similar manner.

*White corpuscles, leucocytes.* These are distinguished from the red corpuscles in having no colour and being more irregular in shape. A cubic millimetre contains on an average 7,000 to 8,000 in adults and 10,000 in children. They are counted in the same way as the red corpuscles, but the blood is only diluted 1 to 10 or 1 to 20. It is desirable to stain before counting to make them more distinct.

*Hæmoglobin.* This is estimated colorimetrically by diluting the blood with water until it agrees with a standard tint and then noting the dilution. Sir W. R. Gower's hæmoglobinometer or one of its modifications is used.

For permanent mounts, the blood is dried for twelve hours on the slide, stained with a strong alcoholic solution of Eosin, and mounted in Canada balsam.

*Alkalinity.* This is estimated by noting the amount of N/1000 sulphuric acid required to produce a precipitate. A series of small tubes are prepared containing quantities of standard acid rising by 0.1 cc. from 0.0 cc. to 1.2 cc. of standard acid, the volume in each case being made up to 2 cc. with distilled water. A drop of blood (0.2 cc.) is then added

to each tube, the contents well mixed, and the tube placed in a water bath at  $45^{\circ}$  for one hour. A slight opalescence appears in all the tubes, but a coarse flocculent precipitate occurs in the tubes containing the larger quantities of acid (0.7 to 0.9 cc.). The appearance of the precipitate is considered to indicate the neutralisation point. (See *J.C.S. Abs.*, ii/10, 317.)

## Recognition of blood-stains.

Stains on linen, etc., are usually identified by moistening with a fresh solution of guaiacum resin in alcohol and then adding a drop of ozonic ether: a blue colour indicates blood. If the blood is mixed with a liquid the guaiacum is added and the ozonic ether poured on; a blue ring indicates blood. Sodium perborate and dilute acetic acid may be used instead of ozonic ether, and will show 1 in 50,000.

Ozonic ether is a solution of 1.2% (= 4 vols.  $O_2$ )  $H_2O_2$  in ether.

Benzidine dissolved in alcohol and acidified with acetic acid gives a similar colour with blood and hydrogen peroxide. The stain is moistened with normal saline solution, absorbed by cotton wool, and the spot, on treatment with benzidine solution and hydrogen peroxide or sodium perborate, gives the blue colour; said to detect 1 in 200,000.

The stain may be moistened with a drop of acetic acid, and then soaked for one or more hours in a 70–80 per cent. solution of chloral hydrate. Stains 10 or 20 years old are thoroughly extracted by this method, and the resulting solution is used for the ozonic ether or benzidine reaction.

The cloth may be plunged into boiling water, placed on a slide, and a few drops of ammonium sulphide added. Examined microspectroscopically it will show absorption bands of hæmochromogen. If on a weapon or piece of jewellery, it is moistened with ammonium sulphide, scraped off and examined as before.

On treating blood stains with a few drops of water, and then a drop of a solution containing  $\frac{1}{2}$  per cent. of mercuric chloride and 2 per cent. of sodium chloride, the blood rises to the top and the corpuscles can be identified microscopically.

Hæmoglobin in solution with a small amount of sodium chloride, evaporated over sulphuric acid to syrupy consistence, then mixed with 15 times its volume of glacial acetic acid and heated on a water bath for several hours, yields, on cooling, flat rhombic crystals of hæmatin hydrochloride with a dark violet colour and lustre.

## THE ALKALOIDS.

E. HOPE, D.Sc.

The term "alkaloid" includes all nitrogen-containing compounds of a basic nature which can be isolated from the organs of plants or animals. It is sometimes used in a narrower sense, implying basic nitrogenous compounds only of vegetable origin, the nitrogen in which forms a member of a heterocyclic ring.

In the appended tables are included a few substances which do not come under either of the above definitions, but these bodies are either derived by very simple reactions from alkaloids or are synthetic substances with physiological properties similar to those of alkaloids.

### Systematic Tests for Alkaloids.

The matter under examination is extracted with an alcoholic solution of tartaric acid. After removal of the alcohol by evaporation and dissolution of the alkaloidal salt in water, the aqueous acid solution is extracted with ether.

*Colchicine* (and some *Caffeine*) will be extracted.

*Colchicine* gives a ppt. with tannic acid solution.

The residual aqueous solution is next made alkaline with sufficient caustic soda to set free bases from salts and to redissolve any morphine. On again extracting with ether most of the alkaloids pass into the ether layer.

i. liquid alkaloids :

*coniine, nicotine.*

ii. solid alkaloids :

(a) a coloration is given by conc.  $\text{H}_2\text{SO}_4$  : *aconitine, delphinine, emetine, hydrastine, narcotine, papaverine, thebaine, veratrine* (*codeine* gives coloration with hot  $\text{H}_2\text{SO}_4$ ) ;

(b) no coloration with conc.  $\text{H}_2\text{SO}_4$ , but coloration with conc.  $\text{HNO}_3$  : *brucine, codeine, strychnine* ;

(c) give neither of above reactions : *atropine, caffeine, cinchonine, cocaine, hyocine, hyocyamine, pilocarpine, physostygmine, quinine.*

The residual alkaline layer is made less strongly basic by addition of ammonium chloride, and is extracted with warm amyl alcohol (at  $50^\circ$ — $60^\circ\text{C.}$ ) or chloroform. The following will be extracted :

*morphine* (coloration with  $\text{HN}\text{O}_3$ ), *narceine* (coloration with conc.  $\text{H}_2\text{SO}_4$ ), and *cytisine*.

The residual liquor may still contain :

*curarine, solanine, apomorphine, berberine.*

These may be extracted by absolute alcohol after evaporation to dryness of the aqueous liquors.

## Alkaloid Reagents.

*Platinic chloride.* 5 per cent. aqueous solution of  $H_2PtCl_6$  gives yellow crystalline or amorphous precipitates, best in presence of alcohol. Alkaloid may be obtained from platinichloride by evaporation with potassium carbonate and extraction.

*Auric chloride.* 1 : 30 aqueous solution. White, yellow or brown precipitates, generally amorphous and soluble in hydrochloric acid.

*Mercuric chloride.* 1 : 20 aqueous solution. White or yellowish precipitates, amorphous or become crystalline, insoluble in hydrochloric acid.

*Tannic acid.* 1 : 10 aqueous solution. White or yellowish precipitates, soluble in hydrochloric acid. Alkaloid recovered by evaporating with litharge and extracting.

*Metatungstic acid.* Tungstic acid is dissolved in a warm solution of an alkali tungstate, the barium salt precipitated and then decomposed with dilute sulphuric acid, and the filtrate evaporated until crystals separate. The aqueous solution is a delicate reagent for quinine and strychnine.

*Picric acid.* Aqueous solution gives yellow amorphous or crystalline precipitates from which the alkaloid may be in certain cases recovered by decomposing with baryta.

*Bouchardat's reagent* ( $KI_3$ ). 1 part of iodine and 2 parts of potassium iodide in 50 parts of water. Brown amorphous precipitates, some becoming crystalline, insoluble in hydrochloric acid.

*Dragendorff's reagent.* 8 grm. of bismuth subnitrate are dissolved in 20 cc. of nitric acid (Sp. Gr. 1.18), and a concentrated solution of 22.7 grm. of potassium iodide added slowly. The mixture is cooled, and the potassium nitrate which crystallises is separated. The solution of  $KBiI_4$  obtained gives orange amorphous precipitates with solutions acidified with sulphuric acid.

*Erdmann's reagent.* 10 drops of dilute nitric acid in 20 cc. of concentrated sulphuric acid.

*Fröhde's reagent.* 1 grm. of ammonium molybdate in 10 cc. of concentrated sulphuric acid.

*Mandelin's reagent* (sulpho-vanadic acid). One per cent. solution of sodium vanadate in conc. sulphuric acid.

*Marmé's reagent*. 10 grm. of cadmium iodide are dissolved in 60 cc. of a warm solution containing 20 grm. of potassium iodide, and an equal volume of a cold saturated solution of potassium iodide added.

*Mayer's reagent*. 13.55 grm. of mercuric chloride and 50 grm. potassium iodide in a litre of water. Amorphous or crystalline precipitates with most alkaloids in slightly acid solution; amorphous precipitates with nicotine and coniine becomes crystalline on standing 24 hours. No precipitate with xanthine or xanthine derivatives.

*Sonnenschein's reagent* (phosphomolybdic acid). Ammonium phosphomolybdate is prepared by addition of sodium phosphate to the usual ammonium molybdate solution. The precipitate is washed and dissolved in 10 per cent. sodium carbonate solution, the solution evaporated to dryness, and the residue ignited after moistening with nitric acid. The residue is dissolved in 30 per cent. nitric acid to give a 10 per cent. solution. Gives yellow to brown precipitates, insoluble in dilute acids, but soluble in concentrated hydrochloric and warm nitric acids. Alkaloid may be obtained from ppt. by warming with barium carbonate and extracting with alcohol.

*Scheibler's reagent*. Sodium tungstate is digested with half its weight of phosphoric acid (Sp. Gr. 1.13) and allowed to stand for some days until crystals of phosphotungstic acid separate. A solution of the crystals gives a precipitate with most alkaloids.



## Colour Reactions of Alkaloids.

| Alkaloid   | Conc.<br>$\text{H}_2\text{SO}_4$    | $\text{HNO}_3$<br>(Sp. Gr. 1.40) | Erdmann's<br>reagent                 | Fröhde's<br>reagent                        |
|------------|-------------------------------------|----------------------------------|--------------------------------------|--|
| Aconitine  | Pale yellow                         | No colrn.                        | Pale yellow                          | Pale yellow                                |
| Atropine   | No colrn.                           | No colrn.                        | No colrn.                            | No colrn.                                  |
| Berberine  | Olive-green                         | Reddish-brown                    | Olive-green                          | Brownish-green                             |
| Brucine    | No colrn.                           | Blood-red                        | Red                                  | Red  |
| Caffeine   | No colrn.                           | No colrn.                        | No colrn.                            | No colrn.                                  |
| Cinchonine | No colrn.                           | No colrn.                        | No colrn.                            | No colrn.                                  |
| Cocaine    | No colrn.                           | No colrn.                        | No colrn.                            | No colrn.                                  |
| Codeine    | Cold, no<br>colrn.;<br>warm, violet | Yellow                           | Yellowish-<br>brown to<br>dull green | Green to blue.                             |
| Colchicine | Yellow                              | Violet to<br>brownish-<br>yellow | Yellow                               | yellow                                     |
| Coniine    | No colrn.                           | No colrn.                        | No colrn.                            | Slowly yellow                              |
| Curarine   | Red                                 | Purple                           | Violet                               | Violet                                     |
| Delphinine | Brown                               | Yellowish                        | Brownish                             | Red-brown                                  |
| Emetine    | Pale brown                          | Yellow                           | Yellow                               | Pale brown                                 |
| Morphine   | No colrn.                           | Yellowish-red                    | Brownish-red<br>to brown             | Violet to green<br>brownish-yellow         |
| Narceine   | Yellow to<br>brownish-<br>yellow    | Yellow,<br>temporary             | Brown to<br>violet to<br>dirty red   | Yellowish-brow                             |
| Narcotine  | Pale yellow<br>to yellowish-<br>red | Yellow to<br>colourless          | Red                                  | Blue-green to<br>green, then<br>red-yellow |
| Nicotine   | No colrn.                           | No colrn.                        | No colrn.                            | No colrn.                                  |
| Papaverine | Violet-blue                         | Yellow to<br>orange              | Dirty violet<br>to blue-green        | Violet-blue to<br>yellow                   |
| Quinine    | No colrn.                           | No colrn.                        | No colrn.                            | No colrn.                                  |
| Strychnine | No colrn.                           | Yellow                           | No colrn.                            | No colrn.                                  |
| Thebaine   | Blood-red to<br>yellowish-red       | Yellow                           | Blood-red to<br>yellowish-red        | Red to reddish-<br>yellow                  |
| Veratrine  | Orange to<br>blood-red              | Yellow                           | Orange to<br>blood-red               | Yellow to red                              |

## Delicacy of Certain Precipitating Agents.

| 1 part alkaloid<br>in parts solution. | $\text{KHgI}_3$         | $\text{KI}_3$ | Picric<br>acid. | Phospho-<br>molybdic.    |
|---------------------------------------|-------------------------|---------------|-----------------|--------------------------|
| Atropine .....                        | 4,000                   | 8,000         | 450             | 4,000                    |
| Brucine .....                         | 30,000                  | 40,000        | —               | 5,000                    |
| Cinchonine .....                      | 50,000                  | 50,000        | 50,000          | 50,000                   |
| Codeine .....                         | 30,000                  | 30,000        | —               | 30,000                   |
| Colchicine .....                      | —                       | 2,500         | —               | 3,300                    |
| Coniine .....                         | 800                     | 10,000        | —               | 1,000                    |
| Morphine .....                        | 1,000<br>(copious ppt.) | 5,000         | (no ppt.)       | 1,000<br>(distinct ppt.) |
| Strychnine .....                      | 8,000                   | 80,000        | 20,000          | 14,000                   |




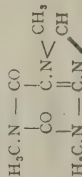
# Characteristics of the Alkaloids.

| Name and Source.   | Formula.   | Behaviour on heating.                          | Parts soluble in 100 parts solvent.                  | Reactions.  |
|--|--|--|--|---|
| Acetomorphine<br>(syn. diamorphine)<br>from morphine   | $C_{17}H_{17}NO_3(C_2H_5O_2)_2$<br>diacetylmorphine  | M.P. 171°                                      | aq 0.11<br>alc. 2.5<br>sol. in acids                 | $HNO_3$ produces a yellow colour; on warming becomes greenish blue and finally yellow. Alc. and $H_2SO_4$ on warming give odour of ethyl acetate.   |
| Acetomorphine hydrochloride  | $C_{16}H_{14}ONCH_3(O.COCH_3)_2, HCl$  | M.P. 231°                                      | aq 33<br>alc. 9<br>insol. in ether                   |   |
| Aconitine<br><i>Aconitum nap.</i> <i>u.</i><br>(monkshood) and<br>other <i>aconitum</i><br>species | $C_{31}H_{27}(OCH_3)_4.NO_5 < \begin{matrix} COCH_3 \\ COC_6H_5 \end{matrix}$<br>acetyl benzoyl aconine                    | M.F. 204—205°                                  | aq 0.02<br>alc. 22<br>ether 50<br>$C_6H_6$ s. sol.   | Conc. $H_2SO_4$ and $HNO_3$ dissolve to colourless solns. Sol. in $H_3PO_4$ gives no coloration on evaporation. Dextrorotatory. Salts laevorotatory. Exceedingly poisonous.                                       |
| Adenine<br>Pancreas, tea and yeast.  | $\begin{array}{c} N = C.NH_2 \\   \\ HC - C - NH \\    \quad    \quad / \\ N - C - N \end{array} + 3H_2O$<br>6-aminopurine | loses aq 110°<br>sublimes 220°<br>decomp. 250° | aq 0.09<br>insol. ether and $CHCl_3$<br>s. sol. alc. | Sol. in dil. ammonia; no ppt. with lead acetate. Neutral reaction.  |
| Adrenaline<br>(syn. adrenalin)<br>suprarenal gland and<br>synthetic                                | $\begin{array}{c} HO \\   \\ HO > C_6H_3 - C - CH_2.NH.CH_3 \\   \\ H \end{array}$<br>dihydroxy phenyl ethanol methylamine | decomp. 207°                                   |  | With ferric chloride, emerald green soln. which with very dil. NaOH becomes purple then carmine. Gold and silver salts reduced. Fehling's soln. reduced on boiling. Soln. in NaOH has odour resembling phosphine. |

| Name and Source.   | Formula.  | Behaviour on heating.                       | Parts soluble in 100 parts solvent.   | Reactions.  |
|--|---|---|---|---|
| Alstonine<br><i>Alstonia constricta</i>                  | $2\text{C}_{31}\text{H}_{20}\text{N}_2\text{O}_4 + 7\text{H}_2\text{O}$   | M.P. 100° anhydr.<br>M.P. 195°<br>M.P. 175° | readily sol. in acids<br>aq 7   | Local anæsthetic.   |
| Amylocaine hydrochloride<br>(synthetic)                  | $\text{CH}_3 > \text{C} \begin{matrix} \text{O.CO.C}_6\text{H}_5 \\ \text{CH}_2.\text{N}(\text{CH}_3)_2\text{HCl} \end{matrix}$<br>dimethyl amino benzoyl dimethyl ethyl carbinol |   |   |   |
| Anagyrene<br><i>Anagyris foetida</i>                     | $\text{C}_{15}\text{H}_{22}\text{N}_2\text{O}$  |   |   | Lævorotatory.   |
| Anhaline<br><i>Anhalonium</i> species<br><i>Cactaceæ</i> | butyl cytisine (?)<br>$\text{C}_{10}\text{H}_{17}\text{NO}$   | M.P. 115°                                   | Sol. in aq, alc., and ether<br>s. sol. aq<br>sol. in alc., ether, and $\text{CHCl}_3$ | Aurichloride M.P. 210°.<br>Soln. in conc. $\text{H}_2\text{SO}_4$ colourless, green on addition of $\text{HNO}_3$ . Yellow soln. in $\text{HNO}_3$ becomes orange on addition of KOH.<br>Not mydriatic. |
| Apoatropine<br>from atropine                             | See atropine<br>..... $\text{CH}_3\text{O.CO.C}:\text{CH}_2\text{C}_6\text{H}_5$  | M.P. 60°                                    | s. sol. aq<br>sol. alc., amyl alc., and $\text{C}_6\text{H}_6$                        |   |
| Apocinchonine<br>from cinchonine                         | $\text{C}_{19}\text{H}_{19}\text{NO}$   |   |   | Ethyl ester M.P. 70°.   |
| Apocodeine<br>from codeine                               | $\text{C}_{18}\text{H}_{19}\text{NO}_2$   | M.P. 209°                                   | Sol. in aq, alc., and in alkalies   | Acetyl ester M.P. 118°<br>Dragendorff's reagent brown ppt. Meyer's reagent dull buff ppt.<br>Hypodermic-purgative.  |
| Apocodeine hydrochloride                                 | $\text{C}_{18}\text{H}_{19}\text{NO}_2\text{HCl}$   | decomp. 200°                                | v. sol. aq<br>sol. alc.   |   |
| Alumorphine<br>from morphine                             | $\text{C}_{17}\text{H}_{17}\text{NO}_2$   | M.P. 295°<br>—300°                          | s. sol. aq<br>r. sol. alc., ether, and $\text{CHCl}_3$                                | White, becoming green on exposure to light and air.<br>Conc. $\text{HNO}_3$ : dull red soln.<br>Fröhde's reagent green.<br>Hypodermic emetic.   |
| Apomorphine hydrochloride                                | $\text{C}_{17}\text{H}_{17}\text{NO}_2\text{HCl}(+\text{H}_2\text{O})$  | M.P. 270°                                   | aq 1.6<br>alc. 2  |   |

| Name and Source.   | Formula.   | Behaviour on heating.                        | Parts soluble in 100 parts solvent.                             | Reactions.   |
|--|--|--|---|--|
| <b>Apoquinine</b><br>from quinine                                  | $C_{19}H_{22}N_2O_2$<br>substitution of $OCH_3$ in quinine by $OH$   | M.P. $210^\circ$                             | sol. in aq, alc., ether, and $NaOH$                             | Solu. not fluorescent.<br>Ethyl ester M.P. $128^\circ$ .   |
| <b>Arecaidine</b><br><i>Areca catechu</i><br>(areca or betel nuts) | $C_7H_{10}NO_2, H_2O$<br>$CH_2CH = C \cdot COOH$<br>$ $<br>$CH_2 \cdot N(CH_2)_3 \cdot CH_3$<br>N—methyl tetrahydronicotinic acid                          | Anhydrous at $100^\circ$<br>M.P. $224^\circ$ | sol. in aq<br>insol. in alc., ether, $CHCl_3$ , and $C_6H_6$    | Aurichloride M.P. $197^\circ$ .<br>Non-poisonous.  |
| <b>Arecaïne</b><br><i>Areca catechu</i>                            | $C_7H_{11}NO_2, H_2O$<br>$CO \cdot CH(CH_2)_3 \cdot CH_3$<br>$ $<br>$CO \cdot CH_2 - \dot{N}CH_3$  | Anhydrous at $100^\circ$<br>M.P. $213^\circ$ | sol. in aq<br>insol. in alc., ether, $CHCl_3$ , and $C_6H_6$    | Dragendorff's reagent red ppt.<br>Aurichloride M.P. $186^\circ$ .  |
| <b>Arecoline</b><br><i>Areca catechu</i>                           | $C_8H_{13}NO_2$<br>$CH_3$ ester of arecaidine<br>$CH_2 \cdot CH = COOCH_3$<br>$ $<br>$CH_2 \cdot N(CH_2)_3 \cdot CH_3$<br>$C_6H_{14}N_2O_2$                | oily liquid<br>B.P. $202^\circ$              | r. sol. aq, alc., ether, and $CHCl_3$                           | Alkaline reaction.<br>Dragendorff's reagent granular red ppt. Phosphomolybdic acid: white ppt.<br>Myotic, very poisonous.<br>Anthelmintic. |
| <b>Arginine</b><br>Lupine and pumpkin seed embryos<br>Albumen      | $NH : C < \begin{matrix} NH_2 \\ NH \end{matrix} \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CH < \begin{matrix} NH_2 \\ COH \end{matrix}$<br>$C_6H_{14}N_4O_2$ |  | Sol. in aq  |  |
| <b>Aricine</b><br><i>Cinchona pubescens</i><br>(Cuscobark)         | $C_{23}H_{34}N_2O_4$   | M.P. $188^\circ$                             | nsol. in aq   | Lævorotatory.<br>Acetate very soluble.   |
| <b>Aspidospermine</b><br><i>Quebracho blanco</i>                   | $C_{32}H_{50}N_2O$   | M.P. $205^\circ$                             | aq 0.016<br>alc. 2.09<br>sol. in ether, $CHCl_3$ , and $C_6H_6$ | Perchloric acid gives red colour.<br>Lævorotatory.   |

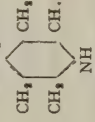
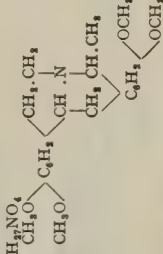



| Name and Source.  | Formula.   | Behaviour on heating.  | Parts soluble in 100 parts solvent.  | Reactions.  |
|---|--|--|--|---|
| Brucine<br><i>Strychnos nux vomica</i><br><i>Strychnos Ignatii</i>  | $C_{23}H_{26}N_2O_4, 4 H_2O$ $[C_{20}H_{20}(OCH_3)_2O]$  $\text{strychnine} + (CH_3O)_2$ | Loses 4 H <sub>2</sub> O at 100°<br>M.P. 178°                        | aq 0.32<br>alc. v. sol.<br>ether s. sol.<br>CHCl <sub>3</sub> 56.7                           | Soln. in H <sub>2</sub> SO <sub>4</sub> is colourless, blood red on addition of trace of HNO <sub>3</sub> .<br>Conc. HNO <sub>3</sub> red, yellow on warming, violet on addition of SnCl <sub>2</sub> .<br>With Na ethylate forms brucic acid.<br>Lævorotatory. Said to be 1/45 as toxic as strychnine. |
| Cephaeline<br><i>Psychotria ippecacuanha</i>  | $C_{25}H_{27} \begin{cases} (OCH_3)_2 \\ OH \\ : NH \\ : N \end{cases}$  | M.P. 102°<br>Cryst. from ether<br>M.P. 96°—98°                       | Sol. in alc.,<br>CHCl <sub>3</sub> . C <sub>6</sub> H <sub>6</sub> ,<br>and s. sol. in ether | Emetic.<br>Lævorotatory $[\alpha]_D = -18^\circ$ .  |
| Caffeine<br>(syn. theine)<br><i>Coffea arabica</i><br>(coffee 1/3—2%)<br><i>Camellia thea</i> (tea 2%)<br><i>Sterculia acuminata</i><br>(kola 2%)<br><i>Paulinia cupana</i><br>(guarana 5%) | $C_8H_{10}N_4O_2, H_2O$  $H_3C.N - CO$ $H_3C.N - \overset{CH}{\underset{  }{C}}.N$      | Anhydr. 100°<br>M.P. 230.5°<br>Sublimes 237°<br>B.P. 384°<br>decomp. | aq 1.25<br>B. aq 50<br>alc. 2<br>ether 0.185   | Moistened with strong HNO <sub>3</sub> , or dissolved in Cl water and evaporated leaves an orange residue turned purple by NH <sub>3</sub> (soln. or gas), discharged by KOH.<br>Not pptd. by Mayer's reagent. Caffeine citrate is an unstable salt hydrolysed by water.                                |

| Name and Source.  | Formula.   | Behaviour on heating.      | Parts soluble in 100 parts solvent.                        | Reactions.  |
|---|--|----------------------------|--|---|
| Cevadine<br>(syn. veratrine)<br><i>Schoenocaulon officinale</i><br>(sabadilla seed) | $C_{32}H_{48}NO_9$ , $2 C_2H_5OH$<br>$C_{27}H_{41}NO_8(OH)O.CO.C_4H_7$ | M.P. 205°<br>(alc. free)   | Insol. in aq<br>sol. in alc.<br>and ether                  | Soln. in warm conc. $H_2SO_4$ is<br>blood red. $H_2SO_4$ with sugar<br>gives green colour becoming<br>blue.<br>Aurichloride M.P. 182°.<br>Optically inactive.<br>Hydrolysed decomp. into<br>cevine and tiglic acid<br>( $C_4H_7COOH$ ).<br>The mixture of alkaloids from<br>sabadilla is also called<br>Veratrine (M.P. 150°)<br>Amorphous.<br>Hydrochloride M.P. 240°. |
| Cevine<br>(syn. cevedine)<br>by hydrolysis of<br>cevadine                           | $C_{27}H_{41}NC_6(OH)_2$   | M.P. 195—200°              | insol. in aq<br>sol. in alc.<br>and ether<br>sol. in acids |   |
| Chelidonine<br><i>Chelidonium majus</i>   | $C_{30}H_9NO$  | M.P. 130°                  | Insol. in aq<br>r. sol. in alc.<br>and ether               | With guaiacum tincture and<br>$H_2SO_4$ gives a carmine colour.<br>Aurichloride forms purple<br>needles.  |
| Cinchonine<br><i>Cinchona</i> species   | $C_{19}H_{22}N_2O$<br>quinine without $CH_3O$ group                    | sublimes 220°<br>M.P. 255° | aq 0.027<br>alc. 0.7<br>ether 0.3<br>$CHCl_3$ 4.3          | Dibasic. Not fluorescent.<br>Dextrorotatory.<br>Alc. soln. $[\alpha]_D = +223.3$ .<br>Sulphate sol. in aq 1 in 100.<br>M.P. 205°  |
| Cinchonidine<br><i>Cinchona</i> species   | $C_{19}H_{22}N_2O$   | M.P. 202°                  | s. sol. aq<br>alc. 6                                       | Lævorotatory. Not fluorescent.<br>Hydrochloride sol. 1 in 20 aq.  |

| Name and Source.  | Formula.  | Behaviour on heating.        | Parts soluble in 100 parts solvent.   | Reactions.   |
|---|---|------------------------------|---|--|
| Cocaine<br><i>Ethyroxylon coca</i><br>(coca leaves)                             | $  \begin{array}{c}  \text{C}_{17}\text{H}_{21}\text{NO}_4 \\    \\  \text{CH}_2 \cdot \text{CH} \text{---} \text{CH} \cdot \text{COOCH}_3 \\    \qquad   \\  \text{NCH}_3 \quad \text{CH} \cdot \text{O} \cdot \text{CO} \cdot \text{C}_6\text{H}_5 \\    \qquad   \\  \text{CH}_2 \cdot \text{CH} \text{---} \text{CH}_2 \\    \\  \text{benzoyl---methyl---ecgonine} \\  \text{C}_{17}\text{H}_{21}\text{NO}_4\text{HCl}  \end{array}  $ | M.P. 98°                     | aq 0.14<br>alc. 10<br>CHCl <sub>3</sub> 200<br>ether 25<br>C <sub>6</sub> H <sub>6</sub> 33                         | Warmed with H <sub>2</sub> SO <sub>4</sub> , evolves vapour of benzoic acid.<br>Hydrolysed decomposes into CH <sub>3</sub> OH, C <sub>6</sub> H <sub>5</sub> COOH and ecgonine. Lævorotatory.<br>Local anæsthetic.   |
| Cocaine hydrochloride   |   | M.P. 183°                    | aq 200<br>alc. 33<br>CHCl <sub>3</sub> 5<br>sol. in hot aq<br>r. sol. in alc.<br>and ether                          | Strong base which forms amorphous salts.   |
| Codamine<br>opium (.3 to 2%)  | C <sub>13</sub> H <sub>18</sub> NO(OH)(OCH <sub>3</sub> ) <sub>2</sub>  | M.P. 121°                    | aq 1.3<br>boil. aq 5.9<br>alc. 50<br>CHCl <sub>3</sub> 50<br>ether 3.3  | Conc. H <sub>2</sub> SO <sub>4</sub> with Fe <sub>2</sub> Cl <sub>3</sub> gives blue soln., soln. in conc. H <sub>2</sub> SO <sub>4</sub> with sugar soln. red colour. Fröhde's reagent gives yellow, green then blue. Lævorotatory.                               |
| Codeine<br>opium (.2 to .8%)<br>and from morphine                               | C <sub>18</sub> H <sub>21</sub> NO <sub>3</sub> , H <sub>2</sub> O<br>methyl-morphine<br>C <sub>17</sub> H <sub>17</sub> NO(OCH <sub>3</sub> ) <sub>2</sub> (OH)  | M.P. 155°<br>anhydr.         | aq 28<br>boil. aq v. sol.<br>alc. 0.5<br>sol. in aq,<br>alc., and CHCl <sub>3</sub><br>v. slightly sol. in<br>ether | Amorphous.<br>Soln. in H <sub>2</sub> SO <sub>4</sub> with HNO <sub>3</sub> , greenish blue colour passing through sky blue to yellow then red. HNO <sub>3</sub> produces dull violet colour becoming greenish then yellow.<br>Lævorotatory.<br>Specific for gout. |
| Codeine phosphate   | C <sub>17</sub> H <sub>19</sub> (CH <sub>3</sub> )NO <sub>3</sub> , H <sub>3</sub> PO <sub>4</sub> , 1½ H <sub>2</sub> O  | Anhydr. at 100°<br>M.P. 235° |   |  |
| Colchicine<br><i>Colchicum autumnale</i><br>(meadow saffron)<br>seeds and corms | $  \begin{array}{c}  \text{C}_{22}\text{H}_{25}\text{NO}_6 \\  \text{C}_{13}\text{H}_9 \quad \left\{ \begin{array}{l} \text{CH}_3 \\ \text{CO} \cdot \text{OCH}_3 \\ \text{NH} \text{ COCH}_3 \end{array} \right.  \end{array}  $   | M.P. 143°                    |   |  |
| Colchicine salicylate   | C <sub>32</sub> H <sub>28</sub> NO <sub>6</sub> , (COO)(OH)   | M.P. 55—60°                  | sol. in aq alc.,<br>and ether   |  |



| Name and Source.   | Formula.   | Behaviour on heating.                 | Parts soluble in 100 parts solvent.  | Reactions.  |
|--|--|---------------------------------------|--|---|
| Colchicine<br><i>Colchicum autumnale</i>                         | $2C_{21}H_{23}NO_6 + H_2O$<br>methyl colchicine  | M.P. 148°<br>anhydrous 172°           | s. sol. in aq<br>insol. in ether<br>v. sol. in alc.<br>and $CHCl_3$              | Same reactions as colchicine.   |
| Coniine<br><i>Conium maculatum</i><br>hemlock<br>(syn. cicutine) | $C_8H_{17}N$<br><br>dextro $\alpha$ propyl piperidine | M.P. -2°<br>B.P. 166°                 | aq. 1<br>v. sol. in alc.,<br>sol. in ether,<br>$CHCl_3$ , benzene<br>and acetone | Volatile liquid with mouse-like odour.<br>Alkaline reaction Sp Gr 0.890.<br>Conc. $H_2SO_4$ gives a blood red colour becoming green.<br>No ppt. with $PtCl_4$ .<br>Aurichloride M.P. 77.<br>Dextrorotatory $[\alpha]_D = +15.7$<br>Intensely poisonous. |
| Conhydrine<br><i>C. maculatum</i>                                | $C_5H_{17}NO$<br>... $C(OH)CH_2CH_2CH_3$<br>oxyconiine   | M.P. (a) 100°<br>(b) 91°<br>B.P. 22½° | s. sol. in alc.,<br>ether, and<br>chl.f.   | Aurichloride M.P. 133°.<br>Dextrorotatory.  |
| Corydaline<br><i>Corydalis cava</i>                              | $C_{23}H_{27}NO_4$<br>                                 | M.P. 134°                             | insol. in aq,<br>sol. in alc.,<br>ether and<br>$CHCl_3$                          | Dextrorotatory.<br>Aurichloride M.P. 207°.  |

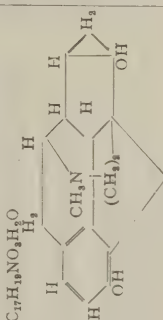
| Name and Source.  | Formula.   | Behaviour on heating.                           | Parts soluble in 100 parts solvent.  | Reactions.   |
|---|--|---|--|--|
| Corynine<br><i>Corynanthe</i><br><i>Yohimbi</i>   | $C_{13}H_{22}N_2O_4$<br>tertiary base  | M.P. 231—234°                                   | v.s. sol. in aq<br>sol. in alc.,<br>methyl alc.,<br>acetone, and<br>$CHCl_3$<br>s. sol. in ether       | Soln. in $H_2SO_4$ is colourless.<br>Soln. in $HNO_3$ is deep green becoming yellow, on addition of KOH (alcoholic) becomes cherry red. Bleaching powder: orange red colour. Dextro-rotatory.            |
| Cotarnine<br>oxidation of narco-<br>tine  | $C_{12}H_{18}NO_4$<br>$OCH_3$<br><br>$CH_2, CH_2, NH, CH_2$ | M.P. 132—135°                                   | s. sol. in aq<br>sol. in alc..<br>v. sol. in ether<br>sol. in $NH_4OH$                                 | Soln. in $HNO_3$ is red.<br>Oxidised by $HNO_3$ yields apophyllenic acid $C_8H_7NO_4$ .<br>Reduced yields hydrocotarine.   |
| Cotarnine<br>hydrochloride<br>Cotarnine phthalate   | $C_{12}H_{18}NO_4HCl$<br>$(C_{12}H_{18}NO_4)_2, C_8H_4(COOH)_2$  | M.P. 102—103°                                   | Readily sol. in<br>alc. and aq<br>Readily sol. in<br>aq  | Yellow crystals. Styptic.  |
| Cornutine<br>Cupreine<br><i>Ramija penduncu-</i><br><i>lata</i> and <i>Cinchona</i><br>species                        | See ergotoxine<br>$C_{19}H_{22}N_2O_2, 2 H_2O$<br>oxycinchonine  | anhydrous at 123°<br>—125°, of wh.<br>M.P. 198° | s. sol. in aq,<br>ether, and<br>$CHCl_3$<br>sol. in alc. and<br>in alkalies,<br>sol. in aq<br>and alc. | Alcoholic soln. with $Fe_2Cl_3$ ,<br>reddish brown; with Cl, then<br>$NH_3$ : dull green.<br>Lævorotatory.<br>Not fluorescent.   |
| Curarine<br>from Curare an ex-<br>tract of <i>Strychnos</i><br><i>toxifera</i> and other<br>species<br>(arrow poison) | $C_{19}H_{28}N_2O$   |   |  | Conc. $H_2SO_4$ gives red; $H_2SO_4$<br>with $K_2Cr_2O_7$ gives blue,<br>becoming violet then red.<br>Intensely poisonous when in-<br>jected hypodermically, almost<br>inert taken orally.<br>Amorphous. |

| Name and Source.   | Formula.   | Behaviour<br>on<br>heating.                | Parts soluble<br>in 100 parts<br>solvent.   | Reactions.  |
|--|--|--|---|---|
| Curine<br>N.B.—Source same<br>as above                                 | $C_{18}H_{18}NO_2$                                     | M.P. 212°<br>Cryst. from alc.<br>M.P. 160° | s. sol. in aq<br>sol. in abs. alc.,<br>$C_6H_6$ and $CHCl_3$  | With Mandelin's reagent, white<br>then bright red.<br>Lavorotatory.   |
| Cusconine<br><i>Cinchona</i> species                                   | $C_{23}H_{28}N_2O_6, 2 H_2O$                           | anhydr. at 100°<br>M.P. 110°               | insol. in aq<br>sol. in alc. and<br>ether   | Lavorotatory.   |
| Cusparine<br><i>Cusparia febrifuga</i><br>( <i>Angostura</i> bark)     | $C_{20}H_{18}NO_2$                                     | M.P. 89°                                   | Sol. in alc.,<br>ether, $CHCl_3$ ,<br>acetone, and<br>$C_6H_6$  | Soln. in conc. $H_2SO_4$ is cherry<br>red; in $HNO_3$ is yellow.<br>Fröhde's reagent, deep blue.<br>Aurichloride M.P. 190°.                                       |
| Cystisine<br><i>Cystisus laburnum</i><br>(laburnum)                    | $C_{11}H_{14}N_2O$<br>dibasic, containing one NH group | M.P. 152°<br>sublimes                      | r. sol. in aq,<br>alc., $C_6H_6$ ,<br>and $CHCl_3$ ;<br>insol. in $CCl_4$<br>sol. in ether<br>and acetone | Dragendorff's reagent dull red<br>deposit; $Fe_2Cl_6$ gives a blood<br>red soln, becoming colourless<br>then blue on addition of<br>$H_2O_2$ . Alkaline reaction. |
| Delphinine<br><i>Delphinium</i><br><i>staphisagria</i><br>(stavesacre) | $C_{21}H_{26}NO_7$                                     | decomp. 120°                               | sol. in abs., alc.,<br>ether 9;<br>$CHCl_3$ 6·25<br>s. sol. in aq   | Optically inactive.   |
| Diamorphine  | See acetomorphine                                      |  |   |   |
| Ditamine<br><i>Alstonia (Echites)</i><br><i>scholaris</i>              | $C_{10}H_{18}NO_2$                                     | M.P. 75°                                   | insol. in aq<br>sol. in ether,<br>$CHCl_3$ and<br>acids   | Conc. $HNO_3$ forms yellow<br>soln., which on warming<br>becomes green then orange<br>red.  |

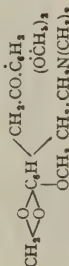
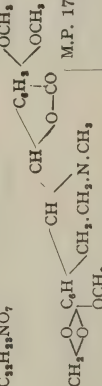
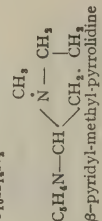
| Name and Source.  | Formula.  | Behaviour on heating.                       | Parts soluble in 100 parts solvent.   | Reactions.   |
|---|---|---|---|--|
| Duboisine<br><i>Duboisia myoporoides</i>  | Mixture of hyoscyamine and hyoscyne   |   |   |  |
| Ecgonine<br>(hydrolysis of cocaine)   | $  \begin{array}{c}  \text{C}_{10}\text{H}_{15}\text{NO}_3 \quad \text{H}_2\text{O} \\  \text{CH}_2 \cdot \text{CH} - \text{CH} \cdot \text{COOH} \\    \\  \text{NCH}_2 \cdot \text{CH} \cdot \text{OH} \\    \\  \text{CH}_2 \cdot \text{CH} - \text{CH}_2 \\    \\  \text{tropine carboxylic acid}  \end{array}  $ | M.P. 205°<br>anhydrous                      | sol. in aq<br>s. sol. in alc<br>sol. in ether   | Mydriatic.<br><br>Lævorotatory.<br>Platinichloride, orange.<br>M.P. 226°   |
| Echitamine<br><i>Astonia (Echites) scholaris</i>  | $  \begin{array}{c}  \text{C}_{22}\text{H}_{28}\text{N}_2\text{O}_4 \quad \text{H}_2\text{O} \\  \text{monobasic}  \end{array}  $   | M.P. 105°<br>anhydrous 206°<br>decomp.      | sol. in aq,<br>alc., acetone,<br>insol. in $\text{C}_6\text{H}_6$<br>sol. in alc.<br>and $\text{CHCl}_3$      | Soln. in conc. $\text{H}_2\text{SO}_4$ is red, on<br>addition of $\text{HNO}_3$ becoming<br>green.<br>Lævorotary. Strongly basic.<br>Soln. in conc. $\text{H}_2\text{SO}_4$ is violet<br>red; in $\text{HNO}_3$ red, then<br>green, finally yellow.<br>Forms amorphous salts.<br>Fröhde's reagent brown on<br>addition of conc. $\text{HCl}$ deep<br>blue $[\alpha]_D = -22^\circ$ |
| Echitenine<br>source same as above  | $\text{C}_{20}\text{H}_{27}\text{NO}_4$   | M.P. 120°                                   | s. sol. in aq<br>sol. in alc.,<br>$\text{CHCl}_3$ , ether,<br>$\text{C}_6\text{H}_6$ and solns.<br>of alkalis | Hydrochloride $[\alpha]_D = +16^\circ$<br>Much less emetic than<br>cephæline.  |
| Emetine<br><i>P sychotria specacuartha</i>  | $  \begin{array}{c}  \text{C}_{29}\text{H}_{40}\text{N}_2\text{O}_4 \\  \text{C}_{27}\text{H}_{27} \left\{ \begin{array}{l} \text{O}(\text{CH}_2)_4 \\ \vdots \text{NH} \\ \vdots \text{N} \end{array} \right.  \end{array}  $  | M.P. 68°                                    | insol. in aq<br>alc. 0.5,<br>hot alc. 2,<br>v. sol. in<br>$\text{CHCl}_3$ ,<br>ether 0.1                      | Ppt. with Meyer's reagent.<br>Soln. in acetic ether with<br>conc. $\text{H}_2\text{SO}_4$ gives an orange<br>coloration, changing to<br>violet. Dextrorotatory.<br>Sat. alc. soln. $[\alpha]_D = +335^\circ$ .<br>Physiologically almost inactive  |
| Ergotamine<br><i>Secale cornutum</i><br><i>Claviceps purpurea</i><br>a fungus growing on<br>rye, <i>secale cereale</i><br>(ergot or spurred<br>rye) | $\text{C}_{25}\text{H}_{40}\text{N}_4\text{O}_6$ (?)<br>anhydride of ergotoxine   | Darkens about<br>210°<br>M.P. about<br>229° |   |  |

| Name and Source.  | Formula.  | Behaviour<br>on<br>heating.      | Parts soluble<br>in 100 parts<br>solvent.                                   | Reactions.  |
|---|---|----------------------------------|---|---|
| Ergotoxine<br>(syn. cornutine)<br>same as above                                 | $C_{28}H_{41}N_5O_4$  | Sottens at 155°<br>M.P. 162—164° | insol. in aq<br>sol. in alc<br>s. sol. in ether<br>v. sol. in NaOH          | Ppt. with Meyer's reagent.<br>Amorphous.<br>HCl salt sol. in aq 1 in 6,000.<br>Strongly active physiologically  |
| Eserine<br><i>Physostigma ven-</i><br><i>enosum</i> (calabar or<br>ordeal bean) | $C_{18}H_{31}N_3O_2$  | M.P. 105—106°                    | s. sol. in aq<br>sol. in alc.,<br>ether, $CHCl_3$<br>and $CS_2$             | Dissolves in conc $HNO_3$ to<br>yellow soln. becoming olive<br>green. Soln. in dil. $H_2SO_4$<br>warmed with $NH_3$ becomes<br>red, yellow, green, then blue.<br>Lavorotatory. Very poisonous.<br>Myotic. |
| Ethyl morphine<br>hydrochloride   | $C_{17}H_{19}NO_2 \cdot C_2H_5Cl$ , $H_2O$                                  | M.P. 124°                        | aq 10 (about)<br>alc. 25<br>hot alc. 100<br>insol. in ether<br>and $CHCl_3$ | Soln. in $H_2SO_4$ colourless,<br>violet on addition of $Fe_2Cl_6$ ,<br>deep red on further addition<br>of $HNO_3$ .  |
| Gelsemine<br><i>Gelsemium nitidum</i><br>(yellow jasmine)                       | $C_{33}H_{50}N_2O_4$<br>contains one OH group                               | M.P. 160°                        | sol. in alc., ether,<br>and $C_6H_6$  | Conc. $HNO_3$ on warming gives<br>a reddish coloration, then<br>dull green. Crystalline.  |
| Guvacin<br><i>Areca catechu</i><br>(areca nuts)                                 | $C_9H_9NO_3$<br>$CO \cdot CH(CH_3) \cdot CH_2$<br> <br>$CO \cdot CH_2$ — NH | M.P. 272°<br>decomp.             | sol. in aq; insol.<br>in alc., ether<br>and $CHCl_3$                        | Aurichloride M.P. 194—195°.   |
| Homatropine<br>from tropine   | $C_6H_{11}NO_3$   | M.P. 99°                         | s. sol. in aq<br>sol. in $CHCl_3$   | Hydrobromide sol. in aq 1 in 6.<br>M.P. 217°. Mydriatic.  |



| Name and Source.   | Formula.   | Behaviour on heating.  | Parts soluble in 100 parts solvent.  | Reactions.   |
|--|--|--|--|--|
| Hyoscyamine<br><i>Hyoscyamine niger</i><br>(henbane)   | $C_{17}H_{23}NO_3$<br>isomeric with atropine   | M.P. $108^{\circ}-5^{\circ}$                                       | sol. in aq. alc.<br>and $CHCl_3$   | Lavortatory $[\alpha]_D^{20} = -21^{\circ}$ .<br>Sulphate M.P. $206^{\circ}$ .<br>Aurichloride M.P. $162^{\circ}$ .<br>Conc. $H_2SO_4$ gives a yellow then dull green.   |
| Jervine<br><i>Veratrum album</i><br>(white hellebore)  | $C_{26}H_{37}NO_3$   | M.P. $238-242^{\circ}$   | sol. in alc.,<br>$CHCl_3$ ,<br>acetone   |  |
| Laudanine<br>Opium   | $C_{20}H_{28}NO_4$   | M.P. $166^{\circ}$   | s. sol. in ether<br>insol. in $C_6H_6$<br>s. sol. in alc.<br>$CHCl_3$<br>s. sol. in ether            | Optically inactive.<br>Solu. in $H_2SO_4$ rose coloured changing to violet on warming<br>Lavortatory.  |
| Lupinine<br><i>Lupinus luteus</i>  | $C_{31}H_{49}N_3O_3$<br>dibasic having 2 OH groups   | M.P. $67^{\circ}$  | s. sol. b. aq  | Aurichloride M.P. $189^{\circ}$ .<br>$C_6H_9N(C_2H_5)_2 \cdot CH_2 \cdot COOH$<br>meroquinene.   |
| Lupinidine<br>Meroquinene<br><i>Cinchona</i> species and<br>from cinchonine                      | $C_{15}H_{25}N_3$<br>$C_{18}H_{25}NO_3$<br>NH $\begin{array}{c} CH_3 - CH_2 \\   \quad   \\ CH_2 - CH - CH_2 \end{array} \cdot CH \cdot CH \cdot COOH$<br>$\beta$ vinyl piperidine acetic acid | B.P. $256^{\circ}$<br>B.P. $311-314^{\circ}$<br>M.P. $222^{\circ}$ | sol. in aq   | $C_8H_9N(COOH)CH_2 \cdot COOH$<br>cincholoiponic acid<br>$C_8H_9N(COOH) \cdot COOH$ loiponic acid.   |
| Morphine<br>Opium (3 to 23%)<br>the dried latex of<br><i>Papaver somniferum</i><br>(white poppy) | $C_{17}H_{19}NO_3 \cdot H_2O$<br>  | anhydr. at $120^{\circ}$<br>M.P. $230^{\circ}$<br>decomp.          | aq 0.01<br>B. aq 0.25<br>hot alc. 7.5<br>insol. in ether<br>v.s. sol. in<br>$CHCl_3$ and<br>$C_6H_6$ | Dissolves in $H_2SO_4$ to colourless soln., on addition of $Fe_2Cl_6$ becomes crimson.<br>Solu. of morphine salts liberate iodine from $HIO_3$ .<br>Neut. $Fe_2Cl_6$ gives blue colour discharged by acids or warming; $K_3FeC_6N_6$ with $Fe_2Cl_6$ (neut.) give blue soln., then blue ppt. Heated to $140-190^{\circ}$ with $HCl$ forms apomorphine $C_{17}H_{17}NO_2$ . |
| Morphine acetate   | Tetrahydro-phenanthrene deriv.<br>$C_{17}H_{19}NO_3 \cdot C_2H_4O_2$   | M.P. $200^{\circ}$ decomp.   | aq 40  | [See over]   |

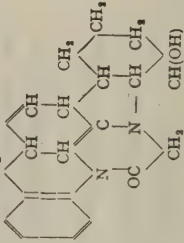
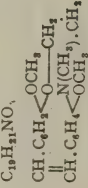


| Name and Source.   | Formula.   | Behaviour on heating.   | Parts soluble in 100 parts solvent.  | Reactions.  |
|--|--|---|--|---|
| Morphine hydrochloride   | $C_{17}H_{19}NO_3 \cdot HCl, 3 H_2O$   | loses 3 $H_2O$ 100°<br>decomp. 250°<br>anhydr. 100°<br>decomp. 250° | aq 4·17<br>boil. aq 100<br>alc. 2  | ( <i>contd.</i> ):<br>Fröhde's reagentet, viol blue, then green.<br>Lævorotatory.   |
| Morphine sulphate  | $(C_{17}H_{19}NO_3)_2 \cdot H_2SO_4, 5 H_2O$   | anhydr. 100°<br>decomp. 250°  | aq 4·5<br>alc. 0·14<br>insol. in $CHCl_3$                                  | Distilled with zinc dust yields phenandrene.  |
| Morphine tartrate  | $(C_{17}H_{19}NO_3)_2 \cdot (CHOHCOOH)_2, 3 H_2O$  | anhydr. at 130°<br>M.P. 145°  | aq 10  | Dilute iodine soln. gives blue colour. Fröhde's reagent green then blood red.   |
| Narceine opium (0·1—0·2%)  | $C_{23}H_{37}NO_8, 3 H_2O$<br> | anhydr. 170°<br>M.P. 145°<br>anhydr. 170°                           | aq 0·1<br>hot aq 0·4<br>alc. 0·1   | Optically inactive.<br>Strongly narcotic.   |
| Narcotine opium (2—10%)  | $C_{33}H_{53}NO_7$<br>         | M.P. 176°   | aq 0·06<br>hot aq 0·15<br>alc. 1<br>hot alc. 0·4<br>ether 1<br>$CHCl_3$ 34 | Conc. $H_2SO_4$ then $HNO_3$ red.<br>Fröhde's reagent green, yellow then colourless.<br>Lævorotatory in neut. solns.<br>Dextrorotatory in acid soln.<br>Narcotine + $H_2O + O =$ cotarnine + opianic acid.                    |
| Nicotine<br><i>Nicotiana tabacum</i><br>(0·6 to 8%)<br><i>N. glutinosa</i> , <i>N. rustica</i> | $C_{10}H_{14}N_2$<br>         | B.P. 247°   | sol. in aq, alc., and ether  | Sp. Gr. 1·01.<br>Conc. $H_2SO_4$ and conc. $HNO_3$ produce no colour, Cl water red to brown colour.<br>Oxidised and distilled with CaO yields pyridine.<br>Lævorotatory [ $\alpha$ ]D = -161·55°<br>Salts are dextrorotatory. |

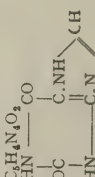
| Name and Source.  | Formula.  | Behaviour on heating.                            | Parts soluble in 100 parts solvent.     | Reactions.   |
|---|---|--|---|--|
| Papavarine<br>Opium (1%)  | $\begin{array}{c} \text{C}_{10}\text{H}_{11}\text{NO}_4 \\ \text{CH}_3\text{O} > \text{C}_{10}\text{H}_4\text{N} \cdot \text{CH}_2 \cdot \text{C}_6\text{H}_3 < \text{OCH}_3 \\ \text{CH}_3\text{O} < \text{OCH}_3 \\ \text{isoquinoline deriv.} \\ \text{C}_8\text{H}_{13}\text{NO} \end{array}$         | M.P. 147°  | insol. in aq sol. in alc. and in ether  | With warm $\text{H}_2\text{SO}_4$ violet. Fröhde's reagent violet then cherry red.   |
| Pelletierine<br>(syn. punicine)<br><i>Punica granatum</i><br>(pomegranate root bark)  |   | B.P. 195° partly decomp.<br>B.P. 125° at 100 mm. | aq 4·3 sol. in alc. and $\text{CHCl}_3$ | Sp. Gr. ·988.<br>Ppt. by $\text{AuCl}_3$ , tannin, Sonnen-schein's reagent, and Bouchardat's reagent. No ppt. with $\text{PtCl}_4$ .<br>Lavorotatory $[\alpha]_D = -30^\circ$ .<br>Inactive at 100°.<br>Salts dextrorotatory.<br>Anthelmintic.   |
| Pelletierine tannate  |   | decomp.  | aq 0·014 alc. 1·25                      |  |
| Physostigmine<br>Pilocarpine<br><i>Pilocarpus jaborandi</i><br><i>P. microphyllus</i> | <p>See Eserine<br/> <math>\text{C}_{11}\text{H}_{16}\text{N}_2\text{O}_2</math><br/> <math>\text{C}_3\text{H}_7 \cdot \text{CH} - \text{CH} \cdot \text{CH}_2 \cdot \text{C}(\text{CO}_2\text{CH}_3)_2 \cdot \text{N} - \text{CH}_2 \cdot \text{CH}(\text{CH}_3) \cdot \text{N}(\text{CH}_3)_2</math></p> | B.P. 261° at 10 mm.                              | sol. in aq, alc., and $\text{CHCl}_3$   | Syrupy liquid. $[\alpha]_D = +100 \cdot 5^\circ$<br>Picrate, sol. in alc. M.P. 160°.<br>Ppt by $\text{AuCl}_3$ .<br>$\text{H}_2\text{SO}_4$ with $\text{K}_2\text{Cr}_2\text{O}_7$ gives grass green colour.<br>Heated to 180° forms pilocarpidin<br>$[\alpha]_D + 90^\circ$ to $92^\circ$ . |
| Pilocarpine hydrochloride   | $\text{C}_{11}\text{H}_{16}\text{N}_2\text{O}_2, \text{HCl}$  | M.P. 204—205°                                    | v. sol. in aq alc. 10                   |  |
| Pilocarpine nitrate   | $\text{C}_{11}\text{H}_{16}\text{N}_2\text{O}_2, \text{HNO}_3$  | M.P. 176°  | aq 12·5 alc. 2 sol. in aq and alc.      | $[\alpha]_D$ above $+80^\circ$ .   |
| Pilocarpidine<br>same as above  | $\begin{array}{c} \text{C}_{10}\text{H}_{14}\text{N}_2\text{O}_2 \\ \text{C}_3\text{H}_4\text{N} \cdot \text{C}(\text{CH}_3)_2 \cdot \text{N}(\text{CH}_3) \\   \\ \text{COOH} \end{array}$   |  |   | Syrupy liquid.<br>$\text{HCl}$ soln. $[\alpha]_D = +72^\circ$ .<br>Aurichloride M.P. 120—124°.   |



| Name and Source.                   | Formula.  | Behaviour on heating.                       | Parts soluble in 100 parts solvent.   | Reactions.  |
|------------------------------------|---|---|---|---|
| Quinine acetyl salicylate          | $C_{30}H_{24}N_2O_2 \cdot C_6H_4 \cdot COOH \cdot O \cdot COCH_3$   | M.P. 157°                                   | aq 0.03 alc. 2<br>CHCl <sub>3</sub> 14  | Almost tasteless.   |
| Quinine ethyl carbonate            | $C_{20}H_{24}N_2O_2 \cdot C_2H_5CO_2$   | M.P. 95°                                    | s. sol. aq<br>r. sol. alc.  |   |
| Quinine hydrobromide               | $C_{20}H_{24}N_2O_2 \cdot HBr$ , $H_2O$   | anhydr. at 100°<br>melts 150—200°           | aq 1.8<br>B. aq 100<br>alc. 143   | Soln. not fluorescent.  |
| Quinine hydrochloride              | $C_{20}H_{24}N_2O_2 \cdot HCl$ , $2 H_2O$   | anhydr. at 130°<br>M.P. 196°                | aq 2.5<br>B. aq 100<br>alc. 100   |   |
| Quinine acid hydrochloride         | $C_{20}H_{24}N_2O_2$ , $2 HCl$ , $3 H_2O$   | anhydr. at 100°<br>M.P. 183—187°<br>decomp. | aq 133<br>alc. 20   | Solns. fluorescent.   |
| Quinine salicylate                 | $(C_{20}H_{24}N_2O_2 \cdot HC_7H_5O_2)_2$ , $H_2O$  |   | v.s. sol. in aq<br>alc. 24  |   |
| Quinine acid sulphate              | $C_{20}H_{24}N_2O_2$ , $H_2SO_4$ , $7 H_2O$   | M.P. 160°<br>decomp.                        | aq 10<br>alc. 2.2   | Lævotatory.<br>5% soln. in 200 mm. tube—22°<br>Antipyretic.<br>Specific in malaria and ague.  |
| Quinine sulphate                   | $[(C_{20}H_{24}N_2O_2)_2 \cdot H_2SO_4]_2$ , $15 H_2O$  | anhydr. at 100°<br>M.P. 205°                | aq 0.125<br>B. aq 4<br>alc. sol. in<br>dil. acids   |   |
| Scopolamine                        | See hyoscine  |   |   | Dissolves in conc. $H_2SO_4$ to<br>rose coloured soln.<br>With $H_2SO_4$ and ammon.<br>vanadate yields a brown colour<br>changing to red then colour-<br>less on addition of water.<br>With $H_2SO_4$ and ammon.<br>vanadate yields red colour. |
| Solanine<br><i>Solanum</i> species | $2C_{25}H_{43}NO_{18}$ , $H_2O$<br>$C_{52}H_{83}NO_{18} = 2 C_6H_{12}O_6 + 4 H_2O$<br>+ $C_{40}H_{61}NO_2$<br>solanidin | M.P. 244°                                   | sol. in 85% alc.<br>s. sol. in abs.,<br>alc., ether<br>insol. in $C_6H_6$<br>and $CH_3Cl_3$ |   |
| Solanine<br>same as above          | $C_{42}H_{83}NO_{18}$   | M.P. 208                                    | sol. in 85% alc.  |   |

| Name and Source.   | Formula.  | Behaviour on heating.                       | Parts soluble in 100 parts solvent.   | Reactions.   |
|--|---|---|---|--|
| Sparteine<br><i>Cytisus scoparium</i><br>(broom)   | $C_{15}H_{26}N_2$<br>pyridine derivative identical with lupinine (?)  | B.P. 311° under 723 m.m., 180° under 20 mm. | s. sol. aq. viscous liquid.<br>sol. in alc., ether and $CHCl_3$<br>insol. in $C_6H_6$<br>sol. in alc. and ether           | Alcoholic soln. $[\alpha]_D = -14.6^\circ$ .<br>Aurichloride yellow.   |
| Stachydrine<br><i>Stachys tubifera</i>   | $C_9H_{13}NO_2$ , $H_2O$<br>$C_9H_9 - NH(CH_3)_2$ (?)<br>CO.O   | M.P. 100° hydrous.                          |   | Aurichloride M.P. 190°—210°.   |
| Strychnine<br><i>Strychnos nuxvomica</i> ( $\frac{1}{4}$ to 1%);<br><i>Strychnos ignatia</i> | $C_{31}H_{22}N_2O_2$<br>                              | M.P. 265—266°<br>B.P. 270° under 5 mm.      | aq 0.014<br>boil. aq 0.04<br>alc. 0.59<br>abs. alc. 0.3<br>boil. abs. alc. 2.5<br>$CHCl_3$ 16.5<br>almost insol. in ether | Moistened with $H_2SO_4$ and $K_2Cr_2O_7$ produces a violet colour, quickly changing to red then yellow. Conc. $HNO_3$ yields a yellow soln.<br>Soln. in $H_2SO_4$ gives with $MnCO_3$ blue colours, rapidly changes to violet, then rose. Lævorotatory. |
| Thebaine<br>opium (0.15%)  | $C_{19}H_{21}NO$ ,<br><br>dihydrophenanthrene deriv. | M.P. 193°                                   | insol. in aq<br>alc. 10<br>s. sol. in ether,<br>sol. in $C_6H_6$<br>and $CHCl_3$  | Dissolves in conc. $H_2SO_4$ to deep red soln. Fröhde's reagent orange.<br>Lævorotatory.<br>alc. soln. $[\alpha]_D = -218.6^\circ$ .   |

| Name and Source.  | Formula.   | Behaviour<br>on<br>heating.         | Parts soluble<br>in 100 parts<br>solvent.                                | Reactions.   |
|---|--|-------------------------------------|--|--|
| <b>Theine (see caffeine)</b><br><b>Theobromine</b><br><i>Theobroma cacao</i><br>(cocoa beans) | $  \begin{array}{c}  \text{C}_7\text{H}_8\text{N}_4\text{O}_2, \text{H}_2\text{O} \\  \text{CH}_3\text{N}-\text{CO} \\    \\  \text{OC} \cdot \text{C.NCH}_3 \\    \\  \text{HN}-\text{C.N} \\     \quad \diagup \quad \diagdown \\  \text{CH} \quad \quad \text{CH}  \end{array}  $ 3·7-dimethylxanthine                                    | sublimes 290°                       | aq (0°) 0·06<br>aq (100°) 1·82<br>s. sol. alc. and<br>ether.             | Dissolved in Cl water <sup>W</sup> and<br>evaporated leaves brown resi-<br>due, becoming purple on<br>addition of $\text{NH}_3$ .<br>Diuretic. |
| <b>Theophylline</b><br><i>Camellia thea</i><br>(tea)  | $  \begin{array}{c}  \text{C}_7\text{H}_8\text{N}_4\text{O}_2, \text{H}_2\text{O} \\  \text{CH}_3\text{N}-\text{CO} \\    \\  \text{OC} \quad \text{C.NH} \\    \quad    \quad \diagup \quad \diagdown \\  \text{CH}_3\text{N}-\text{C.N} \quad \text{CH}  \end{array}  $ 1·3-dimethylxanthine   | anhyd. at 110°<br>M.P. 264°         | sol. in aq. and<br>alc.  | Dissolved in Cl water and eva-<br>porated leaves red residue,<br>becoming violet on addition<br>of $\text{NH}_3$ .<br>Diuretic.                |
| <b>Irigonelline</b><br><i>Irigonellum</i><br><i>flacum gracum</i><br>(Ienugreek seeds)        | $  \begin{array}{c}  \text{C}_7\text{H}_7\text{NO}_2, \text{H}_2\text{O} \\  \text{CO} \quad \text{O} \\    \quad   \\  \text{CH} \quad \text{CH} \\  \diagdown \quad \diagup \\  \text{C} \quad \text{C} \\    \quad   \\  \text{CH} \quad \text{CH} \\  \diagup \quad \diagdown \\  \text{N.CH}_3  \end{array}  $ methyl nicotinic betaine | M.P. 130°<br>anhyd.<br>decomp. 218° | s. sol. in aq.<br>sol. in alc.<br>insol. in ether<br>and $\text{CHCl}_3$ | Dragendorff's soln. gives red<br>ppt.  |
| <b>Tropine</b><br>from atropine   | $  \begin{array}{c}  \text{C}_8\text{H}_{15}\text{NO} \\  \text{CH}_3\text{CH}-\text{CH}_3 \\    \quad   \\  \text{NCH}_3 \quad \text{CHOH} \\    \quad   \\  \text{CH}_3\text{CH}-\text{CH}_3  \end{array}  $   | M.P. 62°<br>B.P. 233°               | s. sol. in aq<br>and alc.<br>sol. in ether                               | Aurichloride M.P. 210°—212°<br>decomposing.<br>Optically inactive.<br>Not mydriatic.   |

| Name and Source.   | Formula.  | Behaviour on heating.   | Parts soluble in 100 parts solvent.                                      | Reactions.  |
|--|---|---|--|---|
| Truxilline<br>$\beta$ and $\gamma$                                 | $C_{19}H_{23}NO_4$<br>ester of egonine with truxillic acid.<br>$(\alpha \beta \text{ or } \gamma)$<br>$C_6H_5 \cdot CH \cdot CH \cdot CO_2H$<br>$C_6H_5 \cdot \dot{C}H \cdot CH \cdot CO_2H$<br>$\alpha$ truxillic acid | $\alpha$ M.P. $80^\circ$<br>$\beta$ M.P. $45^\circ$                 | sol. in alc., ether, $C_6H_6$ and $CHCl_3$ ,<br>s. sol. in petrol. ether | Amorphous salts amorphous.  |
| Veratrine  | See Cevadine.   |   |  |   |
| Vernine<br><i>Vicia sativa</i> (vetch)<br><i>Trifolium</i> species | $C_{18}H_{20}N_8O_8, 3 H_2O$  |   | insol. in alc.   | Forms guanine when boiled with HCl.   |
| Vicine<br><i>Vicia sativa</i> (vetch)                              | $C_{28}H_{51}N_{11}O_{11}, 2 H_2O$  | anhydr. at $120^\circ$<br>M.P. $180^\circ$<br>decomp.<br>M.P. $122$ | sol. in aq., acids and alkalies.<br>aq 1<br>insol. in abs. alc.          | Insol. comp. formed with $Hg(NO_3)_2$<br>Soln. of salts with a trace of $Fe_2Cl_6$ , then $NH_3$ becomes deep blue.   |
| Wrightine  | $C_{24}H_4N_2$  | decomp. $150^\circ$   | sol. in alc. and ether<br>aq 0.007<br>insol. in alc. and ether           | Dissolves in conc. $H_2SO_4$ , to green soln. becoming violet.<br>Soln. evaporated with Cl water and a trace of $HNO_3$ , leaves a yellow residue, reddened by $NH_3$ gas. Soln. in dil. $HNO_3$ , evaporated, residue just dissolved in KOH and again evaporated leaves blue residue |
| Xanthine<br>in flesh, urine,<br>tea, etc.                          | $C_5H_4N_4O_2$<br>   |   | sol. in acids and alkalies   |   |
| Yohimbine  | 2.6-dioxypurine<br>See Corynine.  |   |  |   |
| Yohimbenine<br><i>Cornanthe yohimbi</i>                            | $C_{32}H_{45}N_3O_6$  | M.P. $135^\circ$  | sol. in alc. and $CHCl_3$ ,  | Dissolves in conc. $H_2SO_4$ , to light yellow soln.  |



# Pharmaceutical Names of Synthetic Compounds.

J. R. WALMSLEY, Ph.C., F.I.C.

In order to systematise the names the following rules have, as far as possible been adopted :—

Local anæsthetics, if basic, have names ending in *caine*.

Antipyretics have names ending in *in*.

Hypnotics have names ending in *al*.

Antiseptics for external use have names ending in *form*.

- Official names are indicated by "B.P." The names in brackets are the proprietary names, or the names under which the drugs were first introduced into medicine.

|  |   |
|--|---|
| <i>Acetosalin.</i>                             | Acetylsalicylic acid ( <i>Aspirin</i> ).  |
| <i>Acetannin.</i>                              | Diacetyltannin ( <i>Tannigen</i> ).   |
| <i>Acetoxane.</i>                              | Acetyl- <i>p</i> -oxyphenylurethane ( <i>Neurodin</i> ).                                    |
| <i>Acriflavine.</i>                            | See <i>Flavine</i> .  |
| <i>Adrenine</i><br>( <i>Adrenalin</i> , B.P.). | <i>l</i> -Methylamino ethenol catechol.   |
| <i>Albichthol.</i>                             | Albumin ichthosulphonate ( <i>Ichthalbin</i> ).   |
| <i>Alphaform.</i>                              | Bismuth oxyiodogallate ( <i>Airoform</i> ).   |
| <i>Alumnasol.</i>                              | Aluminium $\beta$ -naphthol-sulphonate<br>( <i>Alumnol</i> ).                               |
| <i>Amidopyrin.</i>                             | Dimethylamido-antipyrin ( <i>Pyramidon</i> ).   |
| <i>Amydricaine</i><br><i>hydrochloride.</i>    | Benzoyl-tetramethyl-diamino-ethyl-<br>dimethyl-carbinol hydrochloride<br>( <i>Alypin</i> ). |
| <i>Amylene chloral.</i>                        | Compound of amylene hydrate and<br>chloral ( <i>Dormiol</i> ).                              |
| <i>Amylocaine</i><br><i>hydrochloride.</i>     | Dimethylamino-benzoyl-dimethylethyl-<br>carbinol hydrochloride ( <i>Stovaine</i> ).         |
| <i>Antifebrin.</i>                             | Acetanilide.  |
| <i>Antipyrin.</i>                              | 1-Phenyl-2 : 3-dimethyl-pyrazolone.   |
| <i>Argentichthol.</i>                          | Silver ichthosulphonate ( <i>Ichthargan</i> ).  |
| <i>Argophol.</i>                               | Silver methylene nucleinate ( <i>Sophol</i> ).  |
| <i>Arsenobenzol.</i>                           | 3 : 3'-Diamino-4 : 4'-dihydroxy-1-<br>arseno-benzene hydrochloride<br>( <i>Salvarsan</i> ). |
| <i>Barbitone</i> , B.P.                        | Diethylbarbituric acid ( <i>Veronal</i> ).  |
| <i>Benzalgen.</i>                              | 8-Ethoxy-5-benzoylaminoquinoline<br>( <i>Analgen</i> ).                                     |

|                                    |   |
|------------------------------------|---|
| <i>Benzamine</i> , B.P.            | Benzoyl-vinyl-diacetone-alkamine ( <i><math>\beta</math>-Eucaine</i> ).         |
| <i>Benzocaine</i> .                | <i>p</i> -Aminobenzoic ethyl ester ( <i>Anæthesine</i> ).                       |
| <i>Benzonaphthol</i> .             | $\beta$ -Naphthol benzoate.   |
| <i>Benzoxate</i> .                 | Benzoyl-acetyl-peroxide ( <i>Acetozone</i> ).                                   |
| <i>Betacaine</i>                   | See <i>Benzamine</i> .  |
| <i>Betaform</i> .                  | Bismuth tribromocatechol ( <i>Novoform</i> ).                                   |
| <i>Bismolinide</i> .               | Quinoline bismuth sulphocyanide ( <i>Crurin</i> ).                              |
| <i>Bromanilide</i> .               | <i>p</i> -Bromoacetanilide ( <i>Antiseptin</i> ).                               |
| <i>Brombutol</i> .                 | Tribromo- <i>tert</i> .-butyl alcohol ( <i>Brometone</i> ).                     |
| <i>Bromobehenate</i> .             | Calcium dibromobehenate ( <i>Sabromin</i> ).                                    |
| <i>Bromophin</i> .                 | Apomorphine bromo-methylate.  |
| <i>Bromovaletin</i> .              | $\alpha$ -Bromo-isovaleryl- <i>p</i> -phenetidine ( <i>Phenoval</i> ).          |
| <i>Butocresiol</i> .               | Di-isobutyl-cresol-iodide ( <i>Europfen</i> ).                                  |
| <i>Cetosalol</i> .                 | Acetyl- <i>p</i> -aminophenol salicylic ester ( <i>Salophen</i> ).              |
| <i>Chloramide</i> , B.P.           | Chloral-formamide ( <i>Chloralamide</i> ).                                      |
| <i>Chloramine T</i> .              | Sodium toluene <i>p</i> -sulphonchloramide.                                     |
| <i>Chlorbutol</i> .                | Trichloro- <i>tert</i> .-butyl alcohol ( <i>Chloretone</i> ).                   |
| <i>Chlorpyrin</i> .                | Chloral hydrate antipyrin ( <i>Hypnal</i> ).                                    |
| <i>Citrosalic acid</i> .           | Methylene-citryl-salicylic acid ( <i>Novaspirin</i> ).                          |
| <i>Cresamol</i> .                  | Ethylene-diamine tricresol ( <i>Kresamine</i> ).                                |
| <i>Cyclocaine</i> .                | Isobutyl- <i>p</i> -amino-benzoate ( <i>Cycloform</i> ).                        |
| <i>Deltaform</i> .                 | Basic bismuth dithiosalicylate ( <i>Thioform</i> ).                             |
| <i>Dimargyl</i> .                  | Ethylene-diamine silver nitrate or phosphate ( <i>Argentamin</i> ).             |
| <i>Diamorphine</i> , B.P.          | Diacetylmorphine ( <i>Heroin</i> ).   |
| <i>Dichloramine T</i> .            | <i>p</i> -Toluene sulphon dichloramide.   |
| <i>Dimethylsulphonol</i> .         | Diethylsulphone-diethylmethane ( <i>Tetronal</i> ).                             |
| <i>Ethocaine</i><br>hydrochloride. | <i>p</i> -Amino-benzoyl-diethylaminoethanol hydrochloride ( <i>Novocaine</i> ). |
| <i>Eusol</i> .                     | A solution of hypochlorous acid (0.25—0.3% HClO).                               |
| <i>Feminal</i> .                   | Isoborneol isovalerate ( <i>Gynoval</i> ).                                      |
| <i>Ferriobenate</i>                | Ferric iodobehenate ( <i>Ferrosajodin</i> ).                                    |
| <i>Flavine</i> .                   | Diamino-methyl-acridinium chloride.   |
| <i>Formamine</i> .                 | Hexamethylenetetramine ( <i>Urotropin</i> ).                                    |
| <i>Formamol</i> .                  | Hexamethylenetetramine anhydro-methylene citrate ( <i>Helmitol</i> ).           |

|   |   |
|---|---|
| <i>Formamylum.</i>                          | Condensation product of formaldehyde and starch ( <i>Amyloform</i> ).                         |
| <i>Formichthol.</i>                         | Formaldehyde ichthosulphonate ( <i>Ichthoform</i> ).  |
| <i>Formotan</i>                             | Formaldehyde tannin compound ( <i>Tannoform</i> ).  |
| <i>Gammaform.</i>                           | Bismuth oxy-iodo-dipyrogallate ( <i>Pyroform</i> ).   |
| <i>Gluside, B.P.</i>                        | Benzoic sulphinide ( <i>Saccharin</i> ).  |
| <i>Glycocaine.</i>                          | Diethylglycocol- <i>p</i> -amino- <i>o</i> -hydroxy-benzoic methyl ester ( <i>Nervanin</i> ). |
| <i>Glycopyrin.</i>                          | Antipyrin methyl-ethyl-glycollate ( <i>Astrolin</i> ).  |
| <i>Guaiaglycol.</i>                         | Guaiacol methyl glycollate ( <i>Monotal</i> ).  |
| <i>Guanicaine</i><br><i>hydrochloride.</i>  | Di- <i>p</i> -anisyl-monophenetyl guanidine hydrochloride ( <i>Acain</i> ).                   |
| <i>Hexamine, B.P.</i>                       | Hexamethylenetetramine ( <i>Urotropin</i> ).  |
| <i>Homadrenine</i><br><i>hydrochloride.</i> | Amino-ethanol-catechol hydrochloride ( <i>Arterenol hydrochloride</i> ).                      |
| <i>Homobarbital.</i>                        | Dipropyl barbituric acid ( <i>Proponal</i> ).   |
| <i>Hydurol.</i>                             | Sodium oxymercurisalicylate and amino-oxyisobutyrate ( <i>Asurol</i> ).                       |
| <i>Ichthamol.</i>                           | Ammonium ichthosulphonate ( <i>Ichthyol</i> ).  |
| <i>Iodicyl.</i>                             | Di-iodo-salicylic methyl ester.   |
| <i>Iodisalin.</i>                           | Methylene-iododisalicylic acid.   |
| <i>Iovalurea.</i>                           | Mono-iodo-valeryl urea ( <i>Iodival</i> ).  |
| <i>Malourea, Malonurea.</i>                 | Diethylbarbituric acid ( <i>Veronal</i> ).  |
| <i>Menthival.</i>                           | Menthyl valerate + 30% free menthol ( <i>Validol</i> ).                                       |
| <i>Mercamin.</i>                            | Ethylenediamine mercury sulphate ( <i>Sublamin</i> ).   |
| <i>Mercotan.</i>                            | Mercuric cholate with tannin albuminate ( <i>Mergal</i> ).                                    |
| <i>Mercuritoli</i>                          | Sodium hydroxymercuric toluate ( <i>Afridol</i> ).  |
| <i>Methophan.</i>                           | 8-Methoxy-2-phenylquinoline-4-carboxylic acid.  |
| <i>Methosal.</i>                            | Methoxy-methyl-salicylate ( <i>Mesotan</i> ).   |
| <i>Methoxetin.</i>                          | Methoxy-acetyl- <i>p</i> -phenetidine ( <i>Kryofine</i> ).                                    |
| <i>Methylsulphonal, B.P.</i>                | Diethylsulphone-dimethyl methane ( <i>Trional</i> ).  |
| <i>Methutin.</i>                            | Dimethylaminoantipyrin-butyl-chloral-hydrate ( <i>Trigemin</i> ).                             |
| <i>Monopyrate.</i>                          | Pyrogallol monoacetate ( <i>Eugallol</i> ).   |
| <i>Monoresate.</i>                          | Resorcinol monoacetate ( <i>Euresol</i> ).  |

|  |  |
|--|--|
| <i>Napthoxytol.</i>                        | $\beta$ -Hydroxynaphthyl- <i>o</i> -hydroxy- <i>m</i> -toluic acid ( <i>Epicarín</i> ).                    |
| <i>Neoquinophan.</i>                       | 6-Methyl-2-phenyl-quinoline-4-carboxylic ethyl ester.  |
| <i>Novarsenobenzol.</i>                    | Sodium 3 : 3'-diamino-4 : 4'-dihydroxy-1-arseno-benzene formaldehyde sulphoxylate ( <i>Neosalvarsan</i> ). |
| <i>Novosulphexine.</i>                     | Secondary hexamethylene salicyl sulphonate ( <i>Neoheal</i> ).   |
| <i>Orthocaine.</i>                         | <i>m</i> -Amino- <i>p</i> -hydroxybenzoic methyl ester ( <i>Orthoform</i> ).                               |
| <i>Oxoquin.</i>                            | Hydroxyquinoline sulphate ( <i>Chinosol</i> ).   |
| <i>Paradrin.</i>                           | Ethylamino-acetocatechol ( <i>Homorenón</i> ).   |
| <i>Phenacetin, B.P.</i>                    | <i>p</i> -Acetylphenetidine.   |
| <i>Phenaspetin.</i>                        | Aminoacetyl-phenetidine acetylsalicylate ( <i>Aspirophen</i> ).  |
| <i>Phenazone, B.P.</i>                     | Phenyl-dimethyl-pyrazolone ( <i>Antipyrin</i> ).   |
| <i>Phenazopirin.</i>                       | Antipyrine acetylsalicylate ( <i>Acetopirin</i> ).   |
| <i>Phenocaine</i><br><i>hydrochloride.</i> | Phenetidyl-acetphenetidine hydrochloride ( <i>Holocain hydrochloride</i> ).                                |
| <i>Phenocitrin.</i>                        | <i>p</i> -Phenetidine citrate ( <i>Citrophen</i> ).  |
| <i>Phenomine</i><br><i>hydrochloride.</i>  | <i>p</i> -Hydroxyphenyl-ethylamine hydrochloride ( <i>Tyramine</i> ).                                      |
| <i>Phenosalin.</i>                         | Salicyl- <i>p</i> -phenetidine ( <i>Malakin</i> ).   |
| <i>Piperazinyll.</i>                       | Ethylene-ethenyldiamine ( <i>Lysidine</i> ).   |
| <i>Piperazidin.</i>                        | Diethylene-diamine ( <i>Piperazine</i> ).  |
| <i>Proflavine.</i>                         | 3 : 6-Diamino-acridine sulphate.   |
| <i>Propocaine.</i>                         | <i>p</i> -Aminobenzoic propyl ester ( <i>Propæsin</i> ).   |
| <i>Pyroxylin, B.P.</i>                     | Dinitrocellulose.  |
| <i>Quinalgen.</i>                          | <i>o</i> -Ethoxy- <i>ana</i> -benzoylaminoquinoline.   |
| <i>Quinophan.</i>                          | Phenylquinoline carboxylic acid ( <i>Atophan</i> ).  |
| <i>Resiosol.</i>                           | Bismuth iodoresorcinol sulphonate ( <i>Anusol</i> ).   |
| <i>Sal Alembroth.</i>                      | Mercuric ammonium chloride<br>$\text{HgCl}_2(\text{NH}_4\text{Cl})_2\text{H}_2\text{O}$ .                  |
| <i>Salicylsuccinate.</i>                   | Succinyl-disalicylic acid ( <i>Diaspirin</i> ).  |
| <i>Saliglycol.</i>                         | Monoglycol ester of salicylic acid ( <i>Spirosal</i> ).  |
| <i>Salol, B.P.</i>                         | Phenyl salicylate.   |
| <i>Sigmaform.</i>                          | Bismuth tribromophenate ( <i>Xeroform</i> ).   |
| <i>Scarlet red.</i>                        | Amino-azo-toluene $\beta$ -naphthol.   |
| <i>Sinetide.</i>                           | Thiosinamine ethyl iodide ( <i>Iodolysin</i> ).  |
| <i>Sodium</i><br><i>acetylarsanilate.</i>  | Sodium acetylaminophenyl arsonate ( <i>Arsacetin</i> ).  |

|                           |   |
|---------------------------|---|
| <i>Sodium</i>             | Sodium aminophenylarsonate ( <i>Soamin</i> ).                                       |
| <i>aminarsonate.</i>      |   |
| <i>Sodium</i>             | Disodium methyl arsinatc ( <i>Arsinyl</i> ).  |
| <i>metharsenite.</i>      |   |
| <i>Sodium barbitone.</i>  | Sodium diethylbarbiturate ( <i>Veronal-sodium</i> ).                                |
| <i>Sodium</i>             | Sodium phenylethylbarbiturate   |
| <i>phenylbarbital.</i>    | ( <i>Luminal-sodium</i> ).  |
| <i>Sozionie acid.</i>     | Di-iodo- <i>p</i> -phenol sulphonie acid  |
|                           | ( <i>Sozoiodol</i> ).   |
| <i>Sulphamipyrin.</i>     | Sodium phenyldimethylpyrazolone-<br>amino-methane sulphonate                        |
|                           | ( <i>Melubrin</i> ).  |
| <i>Sulphexine,</i>        | Hexamethylenetetramine salicyl sul-   |
| <i>Sulphexet.</i>         | phonic acid ( <i>Hexal, Hexalet</i> ).  |
| <i>Sulphiolinic acid.</i> | <i>m</i> -Iodo- <i>o</i> -hydroxyquinoline sulphonie                                |
|                           | acid ( <i>Loretin</i> ).  |
| <i>Sulphocol.</i>         | Potassium-guaiacol sulphonate ( <i>Thiocol</i> ).                                   |
| <i>Sulphonol, B.P.</i>    | Diethylsulphone-dimethyl methane.   |
| <i>Tartradine.</i>        | Dimethylpiperazidine tartrate ( <i>Lycetol</i> ).                                   |
| <i>Tetranitrin.</i>       | Erythrol tetranitrate.  |
| <i>Theosate.</i>          | Theobromine sodium and sodium lactate   |
|                           | ( <i>Theolactin</i> ).  |
| <i>Thiosinamine.</i>      | Allyl thiourea $\text{NH}_2\cdot\text{CS}\cdot\text{NH}\cdot\text{C}_3\text{H}_5$ . |
| <i>Thiosinyl.</i>         | Thiosinamine sodium salicylate  |
|                           | ( <i>Fibrolysin</i> ).  |
| <i>Triketol.</i>          | Phenyl-1 : 2-triketocyclopropanehydrate   |
|                           | ( <i>Ninhydrin</i> ).   |
| <i>Trinitrin, B.P.</i>    | Nitroglycerin.  |
| <i>Tripyrate.</i>         | Pyrogallol triacetate ( <i>Lenigallol</i> ).  |
| <i>Trypaflavine.</i>      | See <i>Flavine</i> .  |
| <i>Uracetin.</i>          | Acetyl- <i>p</i> -ethoxyphenyl urethane   |
|                           | ( <i>Thermordine</i> ).   |
| <i>Uradal.</i>            | Brom-diethyl acetyl urea ( <i>Adalin</i> ).   |
| <i>Uvaleral.</i>          | Monobromo-isovaleryl-urea ( <i>Bromural</i> ).                                      |
| <i>Valide.</i>            | Valeryl-diethylamide ( <i>Valyl</i> ).  |
| <i>Valinopyrin.</i>       | Valeryl-amino-antipyrin ( <i>Neopyrin</i> ).  |
| <i>Valothalein.</i>       | Iso-valeryl-acetyl-phenolphthalein  |
|                           | ( <i>Aperitol</i> ).  |

## Trade Names of Drugs.

- Abrasol*.—Calcium  $\beta$ -naphthol  $\alpha$ -monosulphonate,  $(C_{10}H_7(OH)SO_3)_2Ca$   
Antipyretic.
- Acetal*.—Ethylidene diethyl ether,  $CH_3.CH(OC_2H_5)_2$ . Hypnotic.
- Acetocaustin*.—Trichloroacetic acid. Caustic.
- Acetopyrine*.—Antipyrine acetosalicylate.
- Acetozone*.—Mixture of equal parts of acetyl benzoyl peroxide,  
 $(C_6H_5CO.O.O.C_2H_5O)$  and kieselguhr.
- Achibromin*.—Monobromoisovalerylglycolylurea,  
 $CH_2(OH).CO.NH.CO.NH.CO.C_4H_8Br$ , (28.5% Br).
- Achiodin*.—Monoiodoisovalerylglycolylurea (40% I).
- Acoine*.—Di-*p*-anisylmonophenetylguanidine hydrochloride,  
 $C_2H_5OC_6H_4N:C(NHC_6H_4OCH_3)_2$ . Cocaine substitute.
- Actol*.—Silver lactate.
- Adalin*.—Bromodiethylacetqlurea Hypnotics.
- Adrenalin*, *Adrenal*, *Adrenamine*, *Adneph rin*, *Adrin*.—Products of suprarenal  
gland, natural or synthetic. See Adrenine ("Alkaloids").
- Afridol*.—Sodium hydroxymercuric-*o*-toluate,  $CH_3.C_6H_3(CO_2Na)HgOH$ .
- Agurin*.—Addition product of theobromine-sodium and sodium acetate  
 $C_7H_7N_4O_2Na$ ,  $C_2H_3O_2Na$ . Diuretic.
- Airol*, *Airoform*, *Airogen*.—Bismuth hydroxyiodogallate,  
 $C_6H_2(OH)_3COOBiOH$ .
- Albargin*.—Gelatose-silver (15% Ag.).
- Aletodin*.—Acetylsalicylic acid.
- Aleudrin*.—Carbamic acid ester of *aa*-dichloroisopropyl alcohol,  
 $(CH_2Cl)_2.CH.O.CO.NH_2$ .
- Allosan*.—Santalyl allophanate,  $NH_2.CO.NH.CO_2.C_{15}H_{23}$ .
- Alphogen*, *Alphozone*.—Succinyl peroxide,  $(COOH.CH_2.CH_2.CO)_2O_2$ .
- Alummol*.—Aluminium salt of  $\beta$ -naphthol disulphonic acid,  
 $[C_{10}H_5(OHSO_3)_2]_3Al_2$ . Antiseptic.
- Alypin*.—Tetramethyl-diamino-dimethyl-ethyl-carbinyl-benzoate hydrochloride  
 $C_6H_5.CO.O(C_2H_5)C[CH_2.N(CH_3)_2]_2.HCl$ . Local anæsthetic.
- Amarin*.—Triphenyldihydroglycoxaline,  $C_6H_5.C.NH \begin{matrix} \parallel \\ C_6H_5.C.NH \end{matrix} > CH.C_6H_5$ .
- Aminoform*.—Hexamethylenetetramine.
- Ammonol*.—Ammoniated phenylacetamide.
- Amphotropin*.—Hexamethylenetetramine camphorate,  
 $(C_6H_{12}N_4)_2.C_8H_{14}(COOH)_2$ .
- Amyloform*.—Compound of formaldehyde and starch.
- Anæsthesin*, *Anæsthone*.—Ethyl ester of *p*-aminobenzoic acid,  
 $NH_2.C_6H_4.CO_2C_2H_5$ .
- Analgen*.—8-Ethoxy-5-monobenzoylaminoquinoline or 1-ethoxy-4-acetyl amino  
quinoline.
- Analgesine*.—Antipyrine.
- Analutos*.—Calcium acetylsalicylate.
- Anogon*.—Mercury salt of 2.6-di-iodophenol-4-sulphonic acid,  
 $C_6H_2I_2(OHg)(SO_3Hg)$ .
- Antikamnia*.—Formerly acetanilide and alkali carbonates, now phenacetin.
- Anglopyrin*.—Acetylsalicylic acid.

- Antilueticin.**—Potassium-ammonium-antimony bitartrate.  
 $[\text{SbO}(\text{C}_4\text{H}_4\text{O}_6)_2\text{KNH}_4]_2\text{H}_2\text{O}$ .
- Antiseptine.**—*p*-Bromoacetanilide.
- Antiseptol.**—Cinchonidine iodosulphate.
- Aponal.**—Amylene carbamate,  $\text{NH}_2\cdot\text{COOC}_6\text{H}_{11}$ .
- Apyron.**—Lithium acetylsalicylate.
- Argaldin.**—Combination of albumin silver and hexamethylenetetramine (10% Ag.).
- Argentamine.**—Ethylene-diamine-silver phosphate.
- Argoferment.**—Colloidal silver.
- Argulan.**—Mercury compound of dimethylphenylpyrazolol esulphamine,  
 $\text{C}_{11}\text{H}_{11}\text{N}_2\text{O}\cdot\text{NH}\cdot\text{SO}_3\text{HgOH}$ .
- Argyrol.**—Silver and vitellin compound (20—30% Ag.).
- Aristol.**—Dithymol di-iodide.
- Aristoquinine** (Aristochin).—Carbonic ester of quinine,  $\text{CO}(\text{OC}_{20}\text{H}_{23}\text{N}_2\text{O})_2$ .
- Arrhenal.**—Sodium methylarsinate,  $\text{AsO}(\text{CH}_3)(\text{ONa})_2, 6\text{H}_2\text{O}$ .
- Arsacetin.**—Sodium *p*-acetylaminophenylarsonate  
 $\text{C}_2\text{H}_5\text{O}\cdot\text{NH}\cdot\text{C}_6\text{H}_4\text{AsO}(\text{ONa})(\text{OH}), 5\text{H}_2\text{O}$ .
- Arsacetin-quinine.**—Contains 43% arsacetin and 54% quinine.
- Arsalyt.**—Bismethylaminotetra aminoarsenobenzene.
- Aseptol.**—*p*-Phenolsulphonic acid (33% soln.).
- Aspirin.**—Acetylsalicylic acid.
- Aspirin** (soluble).—Calcium acetylsalicylate.
- Aspirophen.**—Aminoacetphenetidine acetylsalicylate,  
 $\text{C}_2\text{H}_5\text{O}\cdot\text{C}_6\text{H}_4\cdot\text{NH}\cdot\text{C}_2\text{H}_5\text{O}\cdot\text{NH}_2, \text{C}_2\text{H}_5\text{O}\cdot\text{OC}_6\text{H}_4\cdot\text{COOH}$ .
- Asquirrol.**—Mercury dimethoxide,  $(\text{CH}_3\text{O})_2\text{Hg}$ .
- Asyphil.**—Mercury salt of atoxyl,  $[\text{NH}_2\text{C}_6\text{H}_4\cdot\text{AsO}(\text{OH})\text{O}]_2\text{Hg}$ .
- Atophan.**—2-Phenylquinoline-4-carboxylic acid,  $\text{C}_9\text{H}_5\text{N}(\text{C}_6\text{H}_5)\text{COOH}$ .
- Atoxyl.**—Sodium *p*-aminophenylarsinate,  $\text{C}_6\text{H}_7\text{NAsO}_3\text{Na}, 4\text{H}_2\text{O}$  (24% As)
- Benzosalin.**—Methyl-benzoyl salicylate,  $\text{C}_6\text{H}_4(\text{O}\cdot\text{CO}\cdot\text{C}_6\text{H}_5)\text{COOCH}_3$ .
- Benzosol.**—Benzoyl guaiacol, guaiacol benzoate.
- Betol.**— $\beta$ -Naphthyl ester of salicylic acid.
- Bismutose.**—Compound of bismuth 22% and albumin 66%.
- Bornyval.**—Bornyl isovalerate,  $\text{C}_4\text{H}_9\text{CO}\cdot\text{O}\cdot\text{C}_{10}\text{H}_{17}$ .
- Bornyval, New.**—Bornyl isovaleryl glycollate,  $\text{C}_4\text{H}_9\text{COOCH}_2\cdot\text{COOC}_{10}\text{H}_{17}$ .
- Brometone.**—Tribromo tertiary butyl alcohol,  $\text{CBr}_3\cdot\text{C}(\text{CH}_3)_2\text{OH}$ .
- Brominol, Brominoleum.**—Brominated Sesame oil (33% Br)
- Bromipin.**—10% and 33½% Br.—Bromine addition compounds of Sesame oil.
- Bromoglidin, Bromogluten, Bromoprotein.**—Gluten or protein compounds of bromine.
- Bromovalidol.**—Validol with sodium bromide. Sedative.
- Bromural.**—*a*-Bromoisovalerylurea,  $\text{C}_4\text{H}_8\text{Br}\cdot\text{CO}\cdot\text{NH}\cdot\text{CO}\cdot\text{NH}_2$
- Brophenin.**—Bromoisovalerylphenocoll, a brominated phenetidine derivative.
- Cacodyliargol.**—Guaiacol cacodylate,  $(\text{CH}_3)_2\text{AsO}\cdot\text{O}\cdot\text{C}_6\text{H}_4(\text{OCH}_3), \text{H}_2\text{O}$ .
- Calomelol.**—Colloidal calomel,  $(\text{Hg}_2\text{Cl}_2)$ .
- Chloralamide.**—Chloralformamide,  $\text{C}_3\text{H}_4\text{Cl}_3\text{NO}_2$ .
- Chloralose.**—Anhydroglucochloral,  $\text{C}_8\text{H}_{11}\text{Cl}_3\text{O}_6$ , condensation product of chloral and glucose.
- Chloreton.**—Trichloro-tertiary-butyl alcohol,  $\text{CCl}_3\cdot(\text{CH}_3)_2\text{C}\cdot\text{OH}, \frac{1}{2}\text{H}_2\text{O}$ .
- Chromoform.**—Compound of methylhexamethylenetetramine and dichromic acid  
 $(\text{C}_6\text{H}_{12}\text{N}_4\text{CH}_3)_2\text{Cr}_2\text{O}_7$ .
- Chrysoform.**—Dibromo-di-iodohexamethylenetetramine,  $\text{C}_6\text{H}_8\text{Br}_2\text{I}_2\text{N}_4$ .
- Citarin.**—Sodium anhydromethylenecitrate. Gout specific.
- Citrophen.**—Triphenetidine citrate or citro *p*-phenetidine.
- Colchi-sal.**—Colchicine salicylate. Gout specific.



- Coryfin*.—Menthyl ethyl glycollate,  $\text{CH}_2\text{O}(\text{C}_{10}\text{H}_{19})\cdot\text{COOC}_2\text{H}_5$ .
- Coxpyrin*.—Acetosalicic acid.
- Creolin*.—A cresol emulsion.
- Cresolin*, *Creosotal*.—Creosote carbonate, carbonic esters of guaiacol and creosote
- Cryogenin*.—*m*-Benzaminosemicarbazide.
- Cupratin*.—Copper albuminate.
- Cuprol*.—Compound of nucleinic acid and copper.
- Cutal*, *Cutol*.—Aluminium borotannate.
- Cycloform*.—Isobutyl ester of *p*-aminobenzoic acid,  $\text{C}_6\text{H}_4(\text{NH}_2)\text{COOC}_4\text{H}_9$ .
- Cystopurin*.—Compound of hexamethylenetetramine and sodium acetate  
 $\text{C}_6\text{H}_{12}\text{N}_4$ , 2  $\text{C}_2\text{H}_3\text{O}_2\text{Na}$ , 6  $\text{H}_2\text{O}$ .
- Dermatol*.—Bismuth subgallate.
- Dermogen*.—Zinc peroxide.
- Dermol*.—Bismuth chrysophanate.
- Diabetin*.—Lævulose.
- Diogen*.—Acetylene dichloride,  $\text{CHCl}:\text{CHCl}$ .
- Diogenal*.—Dibromopropyldiethylbarbituric acid,  

$$(\text{C}_2\text{H}_5)_2\text{C} \begin{array}{c} \text{CO} \cdot \text{N}(\text{C}_2\text{H}_5\text{Br}_2) \\ \text{CO} \text{---} \text{NH} \end{array} > \text{CO}.$$
- Dionin*.—Ethyl morphine hydrochloride. Sedative.
- Dioxygen*.—A 3% solution of hydrogen peroxide.
- Diplosal*.—Salicylosalicic acid,  $\text{HO} \cdot \text{C}_6\text{H}_4 \cdot \text{CO} \cdot \text{O} \cdot \text{C}_6\text{H}_4 \cdot \text{COOH}$ .
- Dispermin*.—Piperazine  $\text{NH} : (\text{CH}_2 \cdot \text{CH}_2)_2 : \text{NH}$ . Uric acid solvent.
- Diuretin*.—Theobromine sodium salicylate. Diuretic.
- Dormiol*.—Amylene hydrate and chloral compound. Hypnotic.
- Duotol*.—Guaiacol carbonate.
- Ehrlich-Hata* "606" and "614."—Salvarsan and neosalvarsan.
- Elarson*.—Strontium chloro-arseno-behenolate (13% As)
- Electargol*.—Electrolytic colloidal silver.
- Empirin*.—Acetylsalicic acid.
- Eosote*.—Creosote valerate.
- Epicaine*.—Solution of epinine and cocaine hydrochloride
- Epicarine*.—Hydroxynaphthyl-*o*-hydroxytoluic acid.
- Epinine*.—3.4-Dihydroxyphenylethylmethylamine,  
 $(\text{HO})_2\text{C}_6\text{H}_3 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{NH} \cdot \text{CH}_3$ .
- Epinephran*, *Epirenan*.—See Adrenin.
- Epinephrine*.—*o*-Dihydroxy-4-methylaminoethanolbenzene,  
 $(\text{HO})_2\text{C}_6\text{H}_3 \cdot \text{CH}(\text{OH}) \cdot \text{CH}_2 \cdot \text{NH} \cdot \text{CH}_3$ .
- Eprosine*.—1-Methyl-4,5-diphenyleneimidazole.
- Ergamine*.—See *Histamine*.
- $\alpha$ -*Eucaine*.—*N*-methyl-benzoyl-triacetone-alkamine carboxylic acid methyl-  
ester,  $(\text{CH}_3)_2\text{C} \cdot \text{CH}_2$   

$$\begin{array}{c} \text{CH}_3 \cdot \text{N} \cdot \text{C} \begin{array}{c} \text{COOCH}_3 \\ \text{O} \cdot \text{CO} \cdot \text{C}_6\text{H}_5 \end{array} \\ | \\ (\text{CH}_3)_2\text{C} \cdot \text{CH}_2 \end{array}$$
, superseded by  $\beta$ -eucaine.
- $\beta$ -*Eucaine*.—Benzoyl-vinyl-diacetone alkamine,  

$$\begin{array}{c} (\text{CH}_3)_2\text{C} \cdot \text{CH}_2 \\ | \\ \text{H} \cdot \text{N} \cdot \text{CH} \cdot \text{O} \cdot \text{CO} \cdot \text{C}_6\text{H}_5 \\ | \\ \text{CH}_3 \cdot \text{CH} \cdot \text{CH}_2 \end{array}$$
 Local anæsthetic.
- Eudermol*.—Nicotine salicylate. Parasiticide.
- Erphpine*.—Apomorphine methyl bromide.
- Euquinine*.—Quinine ethyl carbonate. Tasteless quinine salt

- Euresol*.—Resorcinol acetate,  $C_6H_4(OH)(O.C_2H_5O)$ .
- Europhen*.—Isobutyl-*o*-cresol iodide. Odourless antiseptic. Antipyretic.
- Exalgin*.—Methyl acetanilide,  $C_6H_5.N(CH_3).CO.CH_3$ .
- Ferratogen*, *Ferrinol*.—Iron nucleinate; contains 21%  $Fe_2O_3$ .
- Fibrolysin*.—15% soln. of combination of thiosinamine (2 mols.) and sodium salicylate (1 mol.).
- Formalin*.—A 40% solution of formaldehyde.
- Formin*.—Hexamethylenetetramine.
- Galyl*.—Tetraoxydiphosphaminodiarsenobenzene (35.3% As).
- Geoform*.—Condensation product of guaiacol and formaldehyde.
- Geosote*.—Guaiacol valerate.
- Glidine*.—Preparations of wheat protein.
- Glutol*, *Glutoform*, *Glutoid*.—Formaldehyde-gelatine.
- Glycosal*.—Salicylic ester of glycerol,  $C_3H_5(OH)_2.O.CO.C_6H_4(OH)$ .
- Gynoval*.—Isobornylisovalerate,  $C_4H_9.COOC_{10}H_{17}$ .
- Hæmogallol*.—Obtained by the action of pyrogallol on defibrinated blood.
- Hectine*.—Sodium benzosulpho-*p* aminophenylarsinate,  
 $C_6H_5.SO_2NA.C_6H_4.AsO(OH)(ONa)$ .
- Hedonal*.—Methylpropylcarbinol urethane,  $CH_3.CH_2.CH_2.CH(CH_3)O.CO.NH_2$ .
- Helicon*.—Acetylsalicylic acid.
- Helmitol*.—Hexamethylenetetramine-anhydromethylene citrate,  
 $C_6H_{12}N_4, C_7H_6O_7$ .
- Hemisine*.—Adrenine.
- Heroin*.—Diacetylmorphine,  $C_{17}H_{17}NO_3(CH_3CO)_2$ .
- Hetoform*.—Basic bismuth cinnamate,  $(C_6H_5.CH:CH.COO)_2Bi, Bi_2O_3$ .
- Hetol*.—Sodium cinnamate,  $C_6H_5.CH:CH.COONa$ .
- Hetralin*.—Compound of resorcinol and hexamethylenetetramine,  
 $C_6H_{12}N_4, C_6H_4(OH)_2$ .
- Hexal*, *Hexalet*.—Hexamethylenetetramine salicylsulphonic acid.
- Hexanatrine*.—Compound of hexamethylenetetramine and acid sodium phosphate.
- Histamine*.— $\beta$ -Iminazolylethylamine.
- Holocain*.—*p*-Diethoxyethenyldiphenylamidine.
- Hopogan*.—Magnesia with 15 or 25%  $MgO_2$ .
- Hydropyrin*.—Lithium acetylsalicylate.
- Hydrosol*.—Aqueous colloidal silver solution.
- Hypnal*.—Chloral antipyrine.
- Hypnogen*.—Diethylbarbituric acid.
- Hypnone*.—Acetophenone,  $CH_3.CO.C_6H_5$ .
- Ichthammon*, *Ichden*, *Ichthyodine*, *Ichthyoson*.—Ichthyol *q.v.*
- Ichthargon*.—Silver ichthyol sulphonate (30% Ag).
- Ichthermol*.—Mercury compound of ichthyol.
- Ichthoform*.—Compound of ichthyol and formaldehyde.
- Ichthyalbin*.—Compound of ichthyol and albumen.
- Ichthyol* (Ammon).—Ammonium salts of sulphonic acids of ichthyol—an oily product of destructive distillation of a bituminous schist from the Tyrol.
- Ichthyolate*.—Sodium salt of above.
- Iodoform*.—Salicylic methylene acetate; from formaldehyde and acetylsalicylic acid.
- Iodal*, *Iodol*.—Tetraiodopyrrole,  $\begin{array}{c} \text{Cl} : \text{Cl} \\ | \quad \diagdown \\ \text{Cl} : \text{Cl} \end{array} \text{NH}.$  Iodoform substitute.
- Iodinol*.—Iodised sesame oil.
- Iodipin*.—Addition compound of Sesame oil containing 10% or 25% I.
- Iodoglidin*.—Preparation of wheat gluten containing 10% iodine.
- Iodoglobin*.—Di-iodotyrosine,  $HO.C_6H_4I_2.CH_2.CH(COOH)NH_2$ .
- Iodolen*.—Combination of iodol (tetra-iodopyrrole) and albumin (30% iodol).

- Iodolysin*.—Similar to iodine contains 43% thiosinamine and 47%  
*Iodophenin*.—Tri-iodo phenacetin.  
*Iodoval*.—Mono-iodoisovalerylurea,  $(\text{CH}_3)_2\text{CH}.\text{CHI}.\text{CO}.\text{NH}.\text{CO}.\text{CH}_2$ .  
*Iodosol*.—Di-iodo-*p*-phenolsulphonic acid,  $\text{C}_6\text{H}_2\text{I}_2(\text{OH})\text{SO}_3\text{H} \cdot 3\text{H}_2\text{O}$ .  
*Iodylin*.—Bismuth iodosalicylate.  
*Iothion*.—Di-iodoisopropyl alcohol,  $\text{CH}_2\text{I}.\text{CH}(\text{OH}).\text{CH}_2\text{I}$ .  
*Isopral*.—Trichloro-isopropyl alcohol,  $\text{CCl}_3.\text{CH}(\text{OH}).\text{CH}_3$ .  
*Istin*.—Synthetic anthraquinone derivative. Laxative.  
*Joha*.—Oily suspension of salvarsan (40%) in iodipin.  
*Jothion*.—See *Iothion*.  
*Kalmopyrine*.—Calcium acetylsalicylate,  $(\text{C}_6\text{H}_4\text{O}.\text{CO}.\text{CH}_3\text{COO})_2\text{Ca}$ .  
*Kephaldol*.—Preparation of phenetidine and salicylic and citric acids in tablets.  
*Kharsine*.—Sodium-*p*-amino-*m*-tolyl arsiniate.  
*Kharsivan*.—Dihydroxydiaminoarsenobenzene dihydrochloride,  
 $\text{HCl}.\text{NH}_2(\text{OH})\text{C}_6\text{H}_3.\text{As}:\text{As}.\text{C}_6\text{H}_3(\text{OH})\text{NH}_2.\text{HCl}, 2\text{H}_2\text{O}$ . Antisyphilitic.  
*Koryfin*.—See *Coryfin*.  
*Lacteol*, *Lactigen*, *Lactiloids*, *Lactobaccilline*, *Lactone*.—Preparations of lactic acid bacilli.  
*Lactol*.— $\beta$ -Naphthol lactic ester.  
*Laxans*, *Laxatol*, *Laxen*, *Laxoin*.—Phenolphthalein *q.v.*  
*Lenigallol*.—Pyrogallol tri- or tetra- acetate.  
*Levurine*, *Levuretin*, *Levurinese*.—Dried yeast.  
*Lithium-diuretin*.—Addition product of theobromine lithium and lithium salicylate.  
*Lodal*.—6-7 Dimethoxy 2-methyl-3,4-dihydro-isoquinolium chloride. Styptic.  
*Luesan*.—Glide preparation of mercury.  
*Luminal*.—Phenyl methyl malonyl urea,  $\text{C}_2\text{H}_5$   
Hypnotic.  

$$\begin{array}{c} \text{C}_6\text{H}_5 \\ | \\ \text{C} \begin{array}{l} \swarrow \text{CO}.\text{NH} \\ \searrow \text{CO}.\text{NH} \end{array} \text{CO} \end{array}$$
  
*Luminal sodium*.—Soluble sodium salt of above.  
*Lysidine*.—Ethylene ethenyl diamine,  $\text{CH}_2.\text{N}$   
Diuretic  

$$\begin{array}{c} | \\ \text{CH}_2.\text{NH} \end{array} \begin{array}{l} \searrow \\ \searrow \end{array} \text{C}.\text{CH}_3$$
  
*Lysoform*.—A liquid formaldehyde potassium soap.  
*Lysol*, *Lysitol*.—Creosol emulsified with soap.  
*Malonal*.—Diethylbarbituric acid. Hypnotic.  
*Maretin*.—*m*-Tolylsemicarbazide,  $\text{CH}_3.\text{C}_6\text{H}_4.\text{NH}.\text{NH}.\text{CONH}_2$ .  
*Medinal*.—Sodium compound of diethyl barbituric acid. Hypnotic.  
*Melubrin*.—Phenyldimethyl pyrazolone aminomethanesulphonic acid; sodium salt.  $\text{C}_{11}\text{H}_{11}\text{N}_2\text{ONHCH}_2.\text{SO}_3\text{Na}$ .  
*Mercuriocolo*, *Mergal*, *Mejodin*, *Merlusin*, *Merchinal*, *Mercoid*.—Organic compounds of mercury.  
*Mercuriol*.—Mercury compound of nucleic acid.  
*Mesotan*.—Salicylic methoxymethyl ester,  $\text{C}_6\text{H}_4.\text{OH}.\text{COOCH}_2.\text{OCH}_3$ .  
Antirheumatic.  
*Methylrhodin*.—Methyl acetylsalicylate,  $\text{C}_2\text{H}_5\text{O}.\text{O}.\text{C}_6\text{H}_4.\text{CO}_2.\text{CH}_3$ .  
*Metramine*.—Hexamine.  
*Migrainine*.—Compound containing 9% caffeine, 90% antipyrin, and 1% citric acid.  
*Migralgine*.—Mixture of antipyrine 88, caffeine 9, and salicylic acid fused together.  
*Monotal*.—Guaiacol methyl glycollate,  $\text{CH}_2(\text{OCH}_3).\text{COOC}_6\text{H}_4.\text{OCH}_3$ .  
Antipyretic and antiseptic.  
*Morphosan*.—Morphine methyl bromide,  $\text{C}_{17}\text{H}_{19}\text{NO}_3.\text{CH}_3\text{Br}, \text{H}_2\text{O}$ .  
Anæsthetic.  
*Mydriatine*.—Atropine methyl bromide,  $\text{C}_{17}\text{H}_{23}\text{NO}_3.\text{CH}_3\text{Br}$ . Mydriatic.  
*Naphthosalol*, *Naphthalol*.— $\beta$ -Naphthyl salicylate,  $\text{C}_6\text{H}_4\text{OH}.\text{COO}.\text{C}_{10}\text{H}_7$ .  
Intestinal antiseptic.  
*Narcyl*.—Ethyl narceine hydrochloride,  $\text{C}_{23}\text{H}_{36}(\text{C}_2\text{H}_5)\text{NO}_6.\text{HCl}$ .  
*Nargol*.—Silver compound of nucleic acid (10% Ag).  
*Neoform*.—Bismuth compound of tro-iodophenol,  $\text{C}_6\text{H}_2\text{I}_2\text{OBi}(\text{OH})_3, \text{Bi}_2\text{O}_3$ .  
*Neohexal*.—Secondary hexamethylenetetramine sulphosalicylate.  
Urinary antiseptic.

- Neokharsivan**.—Sodium 3.3'-diamino-4.4'-dihydroxyarsenobenzene-formaldehyde sulphoxylate,  $\text{NH}_2 \cdot \text{C}_6\text{H}_3(\text{OH})\text{As} \cdot \text{As} \cdot \text{C}_6\text{H}_3(\text{OH})\text{NH}(\text{CH}_2\text{O})\text{SO}_2\text{Na}$ . Anitsyphilitic.
- Neolysol**.—Lysol made with chlor cresol. Odourless antiseptic.
- Neopyrin**.—Valeryl amino-antipyrine.
- Neosalvarsan**.—See *Neokharsivan*.
- Nizin**.—Zinc sulphanyl ate,  $(\text{C}_6\text{H}_4 \cdot \text{NH}_2\text{SO}_3)_2\text{Zn}$ .
- Novargan**.—Protein compound containing 10% silver.
- Novaspirin**.—Methylenecitrylsalicylic acid.
- Novocaine**.—*p*-Aminobenzoylethyldiethylaminoethanol hydrochloride,  $\text{NH}_2 \cdot \text{C}_6\text{H}_4\text{CO} \cdot \text{O} \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{N}(\text{C}_2\text{H}_5)_2\text{HCl}$ .
- Nucleogen**.—Nucleinic compound of iron containing arsenic.
- Orsudan**.—Sodium methyl acetyl-*p*-aminophenylarsinate,  $\text{C}_6\text{H}_5\text{O} \cdot \text{NH} \cdot \text{C}_6\text{H}_3(\text{CH}_3) \cdot \text{AsO}(\text{OH})(\text{ONa})$ .
- Orthoform**.—*p*-Amino-*m*-hydroxy-benzoic-methyl-ester.
- Orthoform, New**.—*m*-Amino-*p*-hydroxy-benzoic-methyl-ester.
- Parolein**.—Refined petroleum, Sp. Gr. \*835.
- Perborax, Perborin, Perboral**.—Sodium perborate.
- Perhydrit**.—Hyperol, 30%  $\text{H}_2\text{O}_2$ .
- Perhydrol**.—Solution of hydrogen peroxide containing 30%  $\text{H}_2\text{O}_2$  or 100 vols. available O.
- Peronine**.—Benzylmorphine hydrochloride,  $\text{C}_{17}\text{H}_{19}\text{NO}_2 \cdot \text{O} \cdot \text{C}_6\text{H}_5 \cdot \text{CH}_2 \cdot \text{HCl}$ .
- Phenagin**.—Phosphoammoniaacetanilide.
- Phenamine**.—Amino-aceto-*p*-phenetidin hydrochloride,  $\text{C}_6\text{H}_5\text{O} \cdot \text{C}_6\text{H}_4 \cdot \text{CO} \cdot \text{CH}_2 \cdot \text{NH}_2 \cdot \text{HCl}$ .
- Phenoval**.—Bromovalerylphenetidin,  $\text{C}_4\text{H}_9\text{Br} \cdot \text{CO} \cdot \text{NH} \cdot \text{C}_6\text{H}_4 \cdot \text{OC}_2\text{H}_5$ .
- Picrastol**.—Dimethylol-diformyl-methenyl-tetramethylene-pentamine,  $\text{C}_6\text{H}_{17}\text{N}_6\text{O}_4$ .
- Piperazine**.—Diethylene-dia nine,  $\text{HN} \begin{array}{c} \diagup \text{CH}_2 \cdot \text{CH}_2 \diagdown \\ \diagdown \text{CH}_2 \cdot \text{CH}_2 \diagup \end{array} \text{NH}$ . Uric acid solvent.
- Proponal**.—Dipropylbarbituric acid,  $(\text{C}_3\text{H}_7)_2\text{C} \begin{array}{c} \diagup \text{CO} \cdot \text{NH} \diagdown \\ \diagdown \text{CO} \cdot \text{NH} \diagup \end{array} \text{CO}$ . Hypnotic.
- Protargol**.—Protein compound of silver (8% Ag).
- Pyoktanin**.—Methyl violet,  $[\text{C}_6\text{H}_4\text{N}(\text{CH}_3)_2]_2(\text{C}_6\text{H}_4 \cdot \text{NH} \cdot \text{CH}_3)\text{CCl}$ . Antiseptic.
- Pyramidon**.—Dimethylaminoantipyrine.
- Quinoform**.—Quinine formate,  $\text{C}_{20}\text{H}_{24}\text{N}_2\text{O}_2$ ,  $\text{HCOOH}$ ; also a condensation product of cinchotannic acid and formaldehyde.
- Rhodaform**.—Hexamethylene-tetramine-methyl-sulphocyanide,  $\text{C}_6\text{H}_{18}\text{N}_4 \cdot \text{CH}_3 \cdot \text{CNS}$ .
- Sabromine**.—Calcium dibromobehenate (29% Br),  $(\text{C}_{22}\text{H}_{41}\text{O}_2\text{Br})_2\text{Ca}$ .
- Sajodin**.—Calcium mon-iodobehenate,  $(\text{C}_{22}\text{H}_{41}\text{O}_2\text{I})_2\text{Ca}$ .
- Saletin**.—Acetyl salicylic acid.
- Saliformin**.—Hexamine salicylate.
- Salit**.—Bornyl salicylate,  $\text{C}_6\text{H}_4 \cdot \text{OH} \cdot \text{COO} \cdot \text{C}_{10}\text{H}_{17}$ .
- Salophen**.—Acetyl-para-aminophenol,  $\text{HO} \cdot \text{C}_6\text{H}_4 \cdot \text{NH} \cdot \text{CO} \cdot \text{CH}_3$ , salicylic ester.
- Salufer**.—Sodium silicofluoride,  $\text{Na}_2\text{SiF}_6$ . Antiseptic.
- Salvarsan**.—See *Kharsivan*.
- Sidonal**.—Urea quinate.
- Sidonal New**.—A mixture of quinic acid,  $\text{C}_6\text{H}_7(\text{OH})_4\text{COOH}$  (25%) and its anhydride (75%). Gout specific.
- Soamin**.—Sodium arsanilate,  $\text{NH}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{AsO}(\text{OH})(\text{ONa})$ , 5  $\text{H}_2\text{O}$ .
- Solurol**.—Thyminic acid (nucleotinphosphoric acid),  $\text{C}_{30}\text{H}_{46}\text{N}_4\text{O}_{15}(\text{P}_2\text{O}_5)_3$ . Uric acid solvent.
- Sophol**.—Silver formonucleinate.
- Sozoiodol**.—Di-iodophenol sulphonic acid.
- Spirarsyl**.—Sodium salt of arsenophenylglycine,  $(\text{CO}_2\text{Na} \cdot \text{CH}_2 \cdot \text{NH} \cdot \text{C}_6\text{H}_4)_2\text{As}_2$ .
- Spirosal**.—Glycol ester of salicylic acid,  $\text{HO} \cdot \text{C}_6\text{H}_4 \cdot \text{COO} \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{OH}$ . Antirheumatic.
- Stovaine**.—Dimethyl-amino-tertiary-amyl-benzoate hydrochloride,  $\text{C}_6\text{H}_5\text{COO} \cdot \text{C}(\text{CH}_3)_2(\text{C}_6\text{H}_5)\text{CH}_2\text{N}(\text{CH}_3)_2\text{HCl}$ . Local anæsthetic.
- Stypticine**.—Cotarnine hydrochloride. Styptic.

- Styptol*.—Cotarnine phthalate. Styptic.
- Sublamine*.—Mercuric ethylene diamine sulphate (43% Hg). Antiseptic.
- Somatose*.—Meat albumose (semi-digested proteid).
- Supradin, Suprarenalin, Suprarenin*.—Adrenalin *q.v.*
- Taka-diastase*.—Enzyme from the fungus, *Eurotium oryzae*, grown on rice.
- Tannalbin*.—A compound of tannin with albumen. Intestinal astringent.
- Tannigen*.—Diacetyl tannin,  $C_{14}H_8(COCH_3)_2O_6$ . Intestinal astringent.
- Tannoform*.—Compound of tannin with formaldehyde,  $C_{26}H_{20}O_{18}$ .
- Tcnocol*.—Compound of tannin and gelatine. Intestinal astringent.
- Tenosin*.—Preparation of active principles of ergot, containing  $\beta$ -iminazoly ethylamine (0.05%) *p*-hydroxyphenylethylamine (2%).
- Tetronal*.—Diethyl-methane-diethylsulphone,  $(C_2H_5)_2 : C : (SO_2.C_2H_5)_2$ . Hypnotic.
- Theocin*.—Theophylline (synthetic), see Alkaloids.
- Theocin-sod. acetate*.—Theophylline sodium acetate. Diuretic.
- Thiocol*.—Potassium guaiacol sulphonate,  $C_6H_3OCH_3OHSO_3K$ . In phthisis.
- Thioform*.—Basic dithio-salicylate of bismuth.
- Thiol*.—Artificial substitute for ichthyol.
- Thiolin*.—Similar to ichthyol.
- Thyresol*.—Santalol methyl ether,  $C_{18}H_{23}O.CH_3$ .
- Tiodine*.—Thiosamine ethyl iodide
- $$S : C \begin{cases} NH.C_2H_5 \\ NH_2.C_2H_5.I \end{cases}$$
- Trional*.—Methyl sulphonal.
- Tumenol*.—Artificial substitute for ichthyol.
- Tyramine*.—*p*-Hydroxyphenylethylamine hydrochloride  
 $HO.C_6H_4.C_2H_4.NH_2, HCl$ .
- Uradal*.—Bromodiethylacetylurea.
- Urisol, Uritone*.—See *Urotropin*.
- Urol*.—Urea compound of quinic acid.
- Urosin*.—Lithium salt of quinic acid,  $C_6H_7(OH)_4COOLi$ .
- Urotropin*.—Hexamethylene tetramine,  $(CH_2)_6N_4$ . See Hexamine.
- Urotropin New*.—Helmitol.
- Ursal*.—Urea salicylate.
- Validol*.—Mentholisovalerianate,  $C_4H_9.CO.O.C_6H_9.CH_3.C_6H_7$ . Sedative.
- Valisan*.—Bornylbromoisovalerianate,  $C_4H_8Br.CO.OC_{10}H_{17}$ .
- Valyl*.—Valeric diethylamide,  $C_4H_9.CO.N(C_2H_5)_2$ .
- Vasogen*.—Oxygenated petroleum.
- Veronal*.—Barbitone, diethylbarbituric acid,  $(C_2H_5)_2 : C : (CO.HN)_2 : C : C$ . Hypnotic.
- Vesipyrrine*. Phenyl acetylsalicylate,  $CH_3.CO.OC_6H_4.COOC_6H_5$ .
- Xaxa*.—Acetylsalicylic acid.
- Xaxaquin*.—Quinine salt of acetylsalicylic acid,  
 $C_{20}H_{24}N_2O_2, CH_3CO.OC_6H_4.COOH$ .
- Xeroform*.—Bismuth tribromophenolate.
- Yohimbine*.—See *Corynine* (Alkaloids).
- Zinol*.—Mixture of alumnol and zinc acetate.

# GLOSSARY OF CERTAIN MEDICAL TERMS.

|                     |   |  |
|---------------------|---|--|
| <i>Alterative</i>   | - | Produces certain changes throughout the system which are not well understood.    |
| <i>Anæsthetic</i>   | - | Produces unconsciousness.  |
| "    (Local)        | - | Causes local insensibility.  |
| <i>Anodyne</i>      | - | Relieves pain.   |
| <i>Analgesic</i>    | - | "    "   |
| <i>Anthelmintic</i> | - | Destroys intestinal parasites.   |
| <i>Antipyretic</i>  | - | Lowers temperature of the body.  |
| <i>Antiseptic</i>   | - | Acts against putrefactive micro-organisms.                                       |
| <i>Aseptic</i>      | - | Free from micro-organisms.   |
| <i>Astringent</i>   | - | Reduces secretion by contraction of the tissues.                                 |
| <i>Carthartic</i>   | - | Purgative.   |
| <i>Diaphoretic</i>  | - | Induces perspiration.  |
| <i>Diuretic</i>     | - | Increases secretion of urine.  |
| <i>Emetic</i>       | - | Causes vomiting.   |
| <i>Emmenagogue</i>  | - | Stimulates menstruation.   |
| <i>Expectorant</i>  | - | Promotes removal of bronchial secretion.   |
| <i>Febrifuge</i>    | - | Reduces body temperature in fever.   |
| <i>Galactagogue</i> | - | Increases secretion of milk.   |
| <i>Hæmostatic</i>   | - | See <i>styptic</i> .   |
| <i>Hormone</i>      | - | Secretion of a gland exciting another organ.                                     |
| <i>Hypnotic</i>     | - | Induces sleep.   |
| <i>Hypodermic</i>   | - | Under the skin (as injections).  |
| <i>Intravenous</i>  | - | Into the veins (as injections).  |
| <i>Laxative</i>     | - | Mild purgative.  |
| <i>Mydriatic</i>    | - | Causes dilation of the pupil of the eye.   |
| <i>Myotic</i>       | - | Causes contraction of the pupil of the eye.                                      |
| <i>Narcotic</i>     | - | Diminishes mental activity.  |
| <i>Pressor</i>      | - | Causes rise of arterial pressure, usually by the constriction of the arterioles. |
| <i>Pyretic</i>      | - | See <i>antipyretic</i> .   |
| <i>Sedative</i>     | - | Soothes the nerves.  |
| <i>Styptic</i>      | - | Arrests bleeding.  |
| <i>Sudorific</i>    | - | See <i>diaphoretic</i> .   |
| <i>Tæniacuge</i>    | - | Promotes expulsion of tæniæ (tape-worms).  |
| <i>Vermifuge</i>    | - | Promotes expulsion of worms.   |

---



## INDIARUBBER.

### *Commercial India-rubber.*

To prepare india-rubber for its various technical uses, the manufacturer has found it necessary in almost every case to vulcanise or "cure" the rubber by either :

- (i) exposing it to the influence of sulphur at temperatures of  $130^{\circ}\text{C}$ . and upwards, if the rubber is in thick masses ;
- or (ii) exposing it to the influence of sulphur monochloride (either in the form of vapour or as a dilute solution of  $\text{S}_2\text{Cl}_2$  in carbon disulphide), at the ordinary temperature. This is only applicable where the rubber is in thin sheets or films.

To increase the resistance of certain rubber goods to the influence of heat, oils, or mechanical abrasion, it has been found advisable to incorporate in the "mixing" inorganic matter, generally oxides, carbonates, or silicates. In order to reduce the price of rubber goods, without increasing to an appreciable extent their specific gravity, additions are made of such organic filling agents as resins, oils, pitches, vegetable fibres, and, most important of all, fatty substitutes. These fatty substitutes are oils, either oxidised (*i.e.* "blown" oils) or vulcanised by heating with sulphur or treating with sulphur chloride. Reclaimed rubber and ground waste rubber are also added to decrease the cost, and in special cases where a peculiar dead toughness is required (*e.g.* in cab tyres), balata and gutta-percha are also added to the mixture.

The most important points to determine in a sample of rubber therefore are :

- (i) India-rubber, recovered rubber, balata, and gutta-percha.
- (ii) Organic matter other than rubber, including
  - Rubber resins, and added resins.
  - Free oil (mineral, fatty, and resin oil) ; also waxes.
  - Fatty substitutes (oxidised or vulcanised oils).
  - Bitumens, tars, pitches (including "mineral rubber").
  - Vegetable fibres, and starches.



(iii) Sulphur and chlorine in india-rubber.

Sulphur and chlorine in substitutes (and in bitumens).

Free sulphur.

Sulphur in inorganic matter.

(iv) Inorganic matter.

### *Sampling.*

In preparing samples for analysis, constructive materials, such as cloth insertions, etc., must first be carefully removed. This is most readily carried out by saturating the fabric with benzene, when it may easily be stripped from the rubber. In the case of thin waterproof cloth the rubber must be scraped from the cloth with a palette knife after the usual treatment with benzene. The rubber so obtained must be dried in a steam oven before it is analysed.

Articles, such as cables, which contain rubbers of different composition, should be separated into their respective layers, and each of these analysed separately; at the same time the ratio of the weights of the different layers to that of the whole article should be determined.

Before analysis all samples should be reduced to a very fine state of division, both to facilitate the extraction with solvents and to ensure an average sample being obtained. This is done by passing the sample through a pair of "mixing rollers," by means of which all correctly vulcanised rubber goods, with rare exceptions, are reduced to a mass of fine flakes. This is repeated until a material sufficiently homogeneous for analysis is obtained. To reduce a sample to a fine state of division by rubbing down on a coarse file is more laborious, but, as such preparation precludes the possibility of altering the rubber hydrocarbons by "mastication" (and thereby increasing the figures for the acetone extract and the loss on saponification), this method should be adopted for all analyses where the highest degree of accuracy is required, and in all cases of research work on vulcanised samples.

## ANALYSIS OF INDIA-RUBBER.

It is occasionally of importance to boil a small quantity of the sample with water, ascertain whether the solution has an acid or alkaline reaction, and whether, after filtering, it leaves a residue which can be further examined. Goods which have been vulcanised with sulphur chloride generally give an acid reaction, and yield sodium chloride in the aqueous extract if they contain "white substitute," in the manufacture of which sodium bicarbonate has been used.

The most suitable organic solvent for the oily and resinous

constituents of india-rubber is acetone, as it will readily dissolve these together with free sulphur and solid hydrocarbons without dissolving a trace of rubber, gutta-percha, or balata.

*Acetone extract.*

The acetone extraction is carried out in a Soxhlet apparatus of 25 cc. to 50 cc. capacity, using 1.5 to 2.0 grms. of the finely ground sample contained in an extraction thimble. The reflux condenser is so arranged that the condensed acetone falls directly into the thimble. For ordinary samples the extraction is complete in about ten hours. The extract is finally dried at 100°C. and weighed. This extract contains :

(i) Rubber resins.

Free oil from substitutes.

Free fatty, mineral, and resin oils.

Resins, and Waxes.

Free sulphur.

The residual rubber still contains :

(ii) India-rubber, gutta, and balata.

Oily substitutes.

Pitches, tars, and bitumens.

Sulphur of vulcanisation.

Sulphur in both organic and inorganic filling materials.

Chlorine in rubber and substitutes.

Inorganic constituents.

If the extract contains waxes or solid resins, even in small quantities, it will be no longer fluid, so that even a viscous liquid extract may safely be assumed to be free from these bodies. On adding 5 cc. of warm absolute alcohol to the extract, any thin liquid residue left undissolved consists of mineral oil. If the solution deposits voluminous flakes on cooling, the presence of wax is practically certain. The amount of fatty oil in the extract may be roughly estimated by saponifying the extracted matter with standard alcoholic potash, titrating the excess with hydrochloric acid, and calculating that 172 mgrm. of potash saponify 1 grm. of fatty oil (calculated as colza oil). The presence of well-shaped crystals of free sulphur in the extract always indicates the absence of oily or resinous ingredients other than those derived from the rubber, or of solid hydrocarbons. The estimation of the free sulphur in such a simple extract may be done by washing out the oily and resinous matter with five portions of 2 cc. of cold acetone, filtering each time into a weighed flask. The filter is washed with 5 cc. carbon

disulphide into the original flask. After the solvents have been driven off, the flasks are dried and the organic extract and sulphur respectively determined by weighing. An error is involved, due to the solubility of sulphur in acetone, to the extent of 5 mgrm. of sulphur in the 10 cc. of acetone used, so that the amount of sulphur must be increased and the organic extract reduced by this amount. In the case of complex extracts, the only satisfactory method for determining the free sulphur is to oxidise the whole of the extract with fuming nitric acid on a water-bath, dilute, filter if necessary wash, and finally precipitate the sulphuric acid with barium chloride.

For the determination of pitches, bituminous bodies, and "mineral rubbers," no satisfactory method is known, as these bodies vulcanise to varying extents, and thus become completely insoluble. The method suggested by C. O. Weber (see below) for their estimation is only useful in so far as it indicates their presence or absence by the colour of the extract *after the first five minutes*. On prolonged extraction with pyridine, as he suggests, all samples of rubber will give a coloured extract, even in the absence of bitumens, as most organic solvents have the power of attacking the vulcanised rubber at 120°C. In addition to this error the fact must be remembered that the vulcanised portion of the bitumen or pitch is scarcely attacked by boiling pyridine, and that therefore the figure given by this extraction has little or no meaning. As it is, however, the only method yet suggested, the following description from Weber is given:

#### *Pyridine extract.*

The extraction with acetone is immediately followed by an extraction with pyridine (B.P. 109°—112°C.), without any intervening drying of the extraction thimble or its contents. The flask is heated on an oil bath (not a sand bath), and kept at 116°—120°C. After extraction the outside of the flask is cleaned with filter paper moistened with benzene, and the flask heated in a water-oven till the smell of pyridine has disappeared. It is then allowed to cool and is weighed.

The estimation of sulphur in all the various forms in which it may occur in manufactured india-rubber being one of the most important points in the complete analysis, it therefore becomes necessary to estimate the sulphur in this extract.

To determine this sulphur, the pyridine extract is oxidised with fuming nitric acid in the flask in which it was weighed. When dissolved it is transferred to a small porcelain dish, the flask washed out with nitric acid, and the washings added to the dish. The liquid is concentrated to a syrupy consistency,

a small amount of sodium acetate added, and the evaporation continued to dryness. The mass is fused and the carbonaceous matter burned off with small additions of sodium nitrate, the melt being allowed to cool. It is then dissolved in water, filtered, washed, and the filtrate acidified with hydrochloric acid. The sulphuric acid formed is precipitated as barium sulphate in the usual manner.

### *Saponification.*

The residue from the pyridine extraction is washed with acetone to remove the last traces of pyridine, and then examined for substitutes by Henrique's method. This consists of drying the residual sample, transferring to a wide-necked flask, and after adding about 25 cc. alcoholic potash (2N), heating on a water-bath with a reflux condenser for six or seven hours. The alcoholic liquor is poured off and preserved, the insoluble residue washed with boiling water till free from alkali, and the washings added to the alcoholic liquor. The residue is dried in an inert atmosphere (usually coal gas) to avoid oxidation, and when cool, weighed. The loss represents the weight of fatty substitutes removed by saponification. In all mixings containing zinc oxide, this treatment with alcoholic potash removes some of the zinc as potassium zincate. This must be estimated in the alcoholic liquors (see later), and a suitable correction made in the loss on saponification. This, like the other data, must be calculated on the weight of the original sample, and not on the weight of the sample of rubber saponified.

As the fatty substitutes present may be oxides, sulphides, or chloro-sulphides of triglycerides, or mixtures of these, it becomes necessary to ascertain which is present, and this is carried out by examination of the alkaline liquor from the saponification process. If of considerable volume, this is evaporated down and then made up with water to 150 cc. Of this 50 cc. are neutralised with concentrated hydrochloric acid, about 1 cc. excess of the acid added, and the zinc content determined by the ferrocyanide process (see Volumetric analysis, Vol. I). The zinc is calculated to zinc oxide and deducted from the total loss on saponification, giving the saponifiable organic matter. A further 50 cc. are taken and evaporated to dryness in a basin, ignited with a small amount of sodium nitrate, cooled, and the mass dissolved in water. On adding nitric acid and silver nitrate the chlorine present is precipitated as silver chloride, which is washed, ignited, and weighed. The chlorine thus found represents the chlorine present in chlorosulphide substitutes.

The remaining 50 cc. are boiled with bromine water and

concentrated to a thick syrup, which is oxidised with nitric acid (fuming), evaporated to dryness, and fused with sodium nitrate, the mass being then dissolved in water. The sulphuric acid present is determined in the usual manner as barium sulphate.

If chlorine and sulphur are both present, and approximately in the ratio of their atomic weights, the substitute present is a chloro-sulphide substitute either alone, or mixed with a "blown" oil substitute. If excess of sulphur be present the substitutes may be chloro-sulphide and sulphide, or a mixture of these with a "blown" oil substitute. In the absence of chlorine, no chloro-sulphide substitute can have been used, and the absence of both chlorine and sulphur prove that the substitute is entirely an oxidised or "blown" oil. A difficulty occurs in connection with this reasoning if a chloro-sulphide substitute is used in hot vulcanised articles, as is often the case, as some of the chlorine leaves the substitute (as hydrochloric acid) during vulcanisation and is absorbed by the rubber and basic inorganic constituents of the mixing. Sufficient chlorine, however, remains in the substitute for its detection.

As a result of saponification a further separation will have been made :

I. *Substance removed by Saponification, and estimated :*

- (a) Chloro-sulphide substitutes.
- (b) Sulphide substitutes.
- (c) Oxidised substitutes.
- (d) Chlorine in substitutes.
- (e) Sulphur in substitutes.

II. *Substances remaining in the Residue (Unsaponifiable) .*

- (a) India-rubber, gutta, and balata.
- (b) Fibres, carbon, etc.
- (c) Chlorine in rubber.
- (d) Sulphur of vulcanisation.
- (e) Sulphur in inorganic matter.
- (f) Inorganic matter.

*Nitronaphthalene "extraction."*

For the separation of the rubber from the inorganic constituents the most direct method is incineration. This answers quite well as a rapid works method for known samples, but is unsatisfactory for unknown samples, as it so interferes with the composition of the mineral matter as to render it impossible to determine its exact nature when originally added to the mixing.



To avoid this difficulty a separation may be effected by digesting the unsaponifiable residue with nitrobenzene or  $\alpha$ -nitronaphthalene (M.P.  $58^{\circ}\text{C}.$ ). These substances completely decompose vulcanised rubber at a temperature of  $170^{\circ}$ — $180^{\circ}\text{C}.$ , nitrobenzene being satisfactory, however, only with samples containing up to 4 per cent. of combined sulphur, whereas nitronaphthalene applies to all cases up to 15 per cent. of combined sulphur, and even higher than this in most instances. The latter also yields solutions which, after diluting with benzene, filter more readily than those produced from the nitrobenzene treatment.

In employing this method it is always advisable to add to the nitrobenzene 8—10 per cent. of chloroform, which lowers the boiling point of the mixture from  $208^{\circ}\text{C}.$  to about  $175^{\circ}\text{C}.$ , thereby preventing the carbonising action on the rubber of any red lead or ferric oxide present (a very marked result when the temperature exceeds  $180^{\circ}\text{C}.$ , and one which increases the figure for "carbon black" in the final results, at the expense of the figure for "india-rubber"). In Weber's nitronaphthalene method the addition of 5 per cent. of chloroform is also beneficial, although the boiling point is scarcely reduced by this addition. It therefore becomes necessary to heat the flask inside an air-bath fitted with a thermostat by means of which a steady temperature of  $180^{\circ}\text{C}.$  is maintained. The method of procedure in this case is to place the residue, the weight of which is known, in a wide-necked flask with 60—70 grm.  $\alpha$ -nitronaphthalene and 3 or 4 cc. of chloroform, and arrange the flask in an air-bath, which almost completely surrounds it. The bath is kept at  $180^{\circ}\text{C}.$  for about an hour, or until solution is complete, when the flask is removed, allowed to cool, about 150 cc. benzene added, and the liquid left to stand for the mineral matter to settle out. The solution is filtered, washed with warm benzene, and dried in a steam-oven. The loss in weight represents rubber, gutta, and balata, together with sulphur and chlorine of vulcanisation. The residue contains the fibres (cotton, etc.), mineral constituents, and, in rare instances, starches. As the rubber, gutta, and balata in the solution are present in a decomposed condition, it is impossible to determine how much of each is present, or in fact, whether any gutta or balata has been used, or whether the rubber was new raw rubber, reclaimed rubber, or ground rubber waste. The best criterion as evidence of the presence of reclaimed or waste rubber is a high degree of vulcanisation in goods where such a figure would not be expected, especially when it occurs in conjunction with a very heterogeneous mineral content, carrying small

percentages of almost every mineral used by the rubber manufacturer.

On washing the residue from the nitronaphthalene extraction with boiling water, using about 200 cc. in all, all dextrine or soluble starch will be removed, and may be estimated.

#### *Estimation of Vegetable fibres.*

The fibrous matter in the residue is next removed by shaking a weighed quantity with chloroform. The mineral matter settles and the chloroform and most of the fibres are poured off into a dish. The mineral matter is again washed until free from fibres, the chloroform being then evaporated from the dish; the remaining fibres are transferred by means of a camel-hair brush to a watch-glass and weighed. From this weight the fibres present in the residue are calculated.

#### *Estimation of Carbon black.*

The carbon black in the residue may be determined (if present, as shown by the colour) by burning off part of the residue with lead chromate in the manner adopted for the elementary analysis of organic bodies containing sulphur. Graphite will also be found as "carbon" in this process.

#### *Mineral Matter.*

Both the qualitative and quantitative analysis of the inorganic constituents in the residue from the nitronaphthalene extraction follow the usual methods of inorganic analysis. The following list gives the minerals most frequently employed by the rubber manufacturer, and may have been added as such to the mixing together with the raw rubber, substitute, sulphur, and the like, or they may have found their way into the goods via the reclaimed rubber or ground rubber waste, with or without the knowledge of the manufacturer:

|  |   |
|--|---|
| Whiting ( $\text{CaCO}_3$ ).                                 | Atmoid ( $\text{SiO}_2$ ).                                  |
| Barytes ( $\text{BaSO}_4$ ).                                 | Magnesium carbonate ( $\text{MgCO}_3$ ).                    |
| Zinc oxide ( $\text{ZnO}$ ).                                 | Gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ).       |
| Lithopone ( $\text{ZnS} + \text{BaSO}_4$ ).                  | White lead ( $\text{Pb}_3\text{C}_2\text{O}_8\text{H}_2$ ). |
| French chalk ( $\text{Mg}_3\text{SiO}_4\text{H}_2$ ).        | Red lead ( $\text{Pb}_3\text{O}_4$ ).                       |
| Asbestos (Mg. Ca. Silicate).                                 | Litharge ( $\text{PbO}$ ).                                  |
| Lime ( $\text{Ca(OH)}_2$ ).                                  | Golden antimony ( $\text{Sb}_2\text{S}_5 + \text{S}$ ).     |
| Magnesia ( $\text{MgO}$ ).                                   | Iron oxide ( $\text{Fe}_2\text{O}_3$ ).                     |
| China clay ( $\text{Al}_2\text{Si}_2\text{O}_5\text{H}_4$ ). | Vermilion ( $\text{HgS}$ ).                                 |

Other substances found in special cases include:

|                   |                    |
|-------------------|--------------------|
| Metallic filings. | Powdered pumice.   |
| Mica.             | Lead thiosulphate. |
| Powdered glass.   | Zinc sulphide      |



In coloured goods which are hot vulcanised, the colours are produced by stable mineral pigments, which require detecting and estimating in the inorganic residue. The most usually employed are :

Antimony sulphide.

Vermilion.

Iron oxide.

Cadmium sulphide.

Zinc yellow.

Hydrated chromium oxide.

Ultramarine.

For "cold cured" goods these colours are replaced by lakes (since in these goods they will not be called upon to withstand the action of molten sulphur and they also give brighter shades). These lakes are precipitated by a solution of alum in the presence of barium chloride, and consist of an aluminium lake of either an acid or basic colour, thrown down on a *blanc fixe* base. Their presence in a rubber mixing is shown by the coloration of the acetone extract. They may be extracted qualitatively with dilute solutions of

(a) alcoholic ammonia, in which the acid colours dissolve;

(b) alcoholic acetic acid, in which the basic colours dissolve.

This should be performed in a test-tube, using a little of the original ground sample.

In many cases it is much more rapid, if not even absolutely necessary, to substitute for chemical analysis a microscopic examination of the insoluble portion of the mineral substances, provided that standard slides are prepared, and kept ready for comparison.

The determination of the sulphur in the inorganic matter is carried out by heating a weighed quantity with fuming nitric acid in a basin on a water-bath, taking the usual precautions to prevent loss through spitting, and concentrating to a syrupy consistency. Sodium acetate is added, the mass evaporated to dryness, and then fused with a small amount of potassium nitrate, allowed to cool, dissolved in boiling water, filtered and washed. Hydrochloric acid is added to the filtrate, and the sulphuric acid precipitated with warm barium chloride and treated in the usual manner. The percentage of sulphur in the mineral matter must be calculated on the initial weight of the original sample.

The amount of sulphide sulphur present in the mineral constituents may be determined by the method of Stevens. When the saponification is complete, a portion of the dry

residue is thoroughly swollen with a solvent such as ether, and treated with warm dilute hydrochloric acid. The hydrogen sulphide evolved is collected and estimated, giving the sulphide sulphur contained in such constituents as zinc sulphide or lead sulphide.

### *Determination of Sulphur and Chlorine.*

The total sulphur is estimated by the method of Waters and Tuttle. About 1 grm. of the sample is treated at 70—80°C. with concentrated nitric acid saturated with bromine, and the liquor concentrated. This treatment is repeated two or three times, concentrated hydrochloric acid added, and the mixture boiled for a few minutes, and then diluted with water. The sulphuric acid formed is estimated in the usual manner.

For the estimation of the sulphur and chlorine combined with the rubber, the most satisfactory method is to extract about 1.5 grm. of the original sample successively with acetone, pyridine and alcoholic potash as before, and then take about 0.3 to 0.4 grm. of the residue for the chlorine estimation and the remainder of the residue for the sulphur estimation, which is performed in the same manner as the determination of total sulphur in the sample. This figure gives the sulphur of vulcanisation plus the sulphur in the inorganic matter, which has been previously determined, and from which the sulphur of vulcanisation may be calculated.

Chlorine is determined by Carius' method, employing 0.3–0.4 grm. prepared rubber (see above), which, together with 5 or 6 cc. fuming nitric acid and 1 grm. of silver nitrate, are heated together for two days in a sealed tube, then carefully opened. The contents are washed out with hot water, and filtered. If all the minerals present in the sample are soluble in nitric acid the precipitate is simply silver chloride, which may be treated and weighed as usual. In the presence of other insoluble matter, the precipitate is washed, dried, and transferred to a crucible, to which the filter-paper is added after incinerating. The contents of the crucible are then mixed with ten times their weight of sodium carbonate, and fused, the melt being cooled, dissolved in water, and filtered. The residue is washed, and then rinsed into a dish, 50 cc. of hot dilute nitric acid being added to the dish by allowing to flow through the filter. The contents of the dish are heated for about ten minutes at near boiling point, filtered, and the residue washed thoroughly until free from acid. To the filtrate is added a slight excess of hydrochloric acid, and the silver chloride is filtered off, washed, ignited, and weighed. From this weight the chlorine in the rubber can be calculated.

A summary of this system for the complete analysis of a vulcanised rubber sample may be drawn up as follows :

I. *Extraction with acetone.*

Rubber resins, oils (fatty, mineral, and resin oils), waxes, resins, and free sulphur.

II. *Extraction with pyridine.*

Tars, bitumens, and pitches (and sulphur in the same).

III. *Extraction with alcoholic potash.*

Substitutes (sulphide, chloro-sulphide, and oxidised oils).

Sulphur and chlorine content.

IV. *Extraction with nitronaphthalene.*

India-rubber, including chlorine and sulphur of vulcanisation (by loss in weight).

V. *Extraction with boiling water.*

Starch and dextrine.

VI. *Washing with chloroform.*

Fibrous matter.

VII. *Examination of residue.*

For carbon, mineral matter, and sulphur in inorganic constituents.

VIII. *Separate determination of total sulphur.*

IX. *Separate determination (after III) for sulphur of vulcanisation.*

X. *Separate determination (after III) for chlorine of vulcanisation.*

A complete analysis is rarely carried out on a sample of rubber, and in practice it is only usual to perform four or five estimations. If, for example, the minerals contain no sulphur in any form, a considerable shortening of the analysis is possible. Moreover, red rubbers, grey rubbers, and drab rubbers contain no pitches, and so Extraction II is unnecessary. Extraction IV may also be eliminated, the rubber being determined by difference. The mineral matter is very frequently determined by incineration, which involves an error, with the most careful working, of up to 2-3 per cent.; but as this only affects the figures for india-rubber and mineral matter, it is not, in the majority of cases, of practical importance.

It should be noted here that in carrying out an ash test on a rubber, the sample should never actually burn, but rather distil, until all evolution of vapours has ceased, when a larger flame may be used. and the carbonaceous matter burned off.

## ANALYSIS OF EBONITE.

As ebonite, or vulcanite, is merely a very highly vulcanised rubber, its analysis follows the methods already indicated for the analysis of india-rubber. There are, however, one or two notable modifications in the treatment which require description.

The preparation of the sample for analysis is of great importance. It is preferable to reduce the sample to a fine powder by means of a large file, pass through a 100 mesh per inch sieve, grinding the material which does not pass through in a mill (a coffee mill answers admirably) until the whole of the sample has passed the sieve. It is then well mixed.

The acetone extraction is performed as usual, but is continued for two or three days, as the free sulphur present appears to be in an amorphous form and only passes into solution very slowly.

As the only organic filling agents in hard rubbers are resins and pitches, and never substitutes, the saponification test is omitted, while the extraction of resins and pitches becomes more important. To remove all the resins, acetone is decidedly unsatisfactory, and in many instances useless, as such substances as shellac (one of the chief organic non-rubber constituents of ebonite), and several other resins, are quite insoluble in acetone. They are, however, soluble in epichlorhydrin, and C. O. Weber suggests this as a solvent to be employed after the acetone extraction and before the pyridine extraction. Weber's method is as follows: The extractor and contents are taken direct from the acetone extraction, and, without drying, connected to a weighed flask containing about 75 cc. of epichlorhydrin (B.P.  $117^{\circ}\text{C}.$ ). The flask is heated on a sand-bath or an asbestos board for three or four hours, removed, and the epichlorhydrin distilled off by heating in a paraffin-bath at  $120^{\circ}\text{C}.$  After wiping the outside of the flask with benzene until clean, it is dried for two hours at  $110^{\circ}\text{C}.$  The extract frequently contains sulphur in organic combination, the amount of which may readily be estimated in the same manner as the sulphur in the pyridine extract. In proceeding next to the extraction with pyridine, it is advisable first to dry the paper thimble and its contents, as pyridine and epichlorhydrin interact.

The extraction is then carried out as before. The sulphur in the residue left from the pyridine extraction is determined in the same manner as the "total sulphur in rubber," and represents the sulphur of vulcanisation *plus* the sulphur in the mineral matter. This latter is calculated

as below, and on deduction from the sulphur contained in the pyridine residue, gives the sulphur of vulcanisation.

The rubber is not determined by the nitronaphthalene extraction, but by difference from 100 per cent. The mineral matter is determined by incineration, and calculation from the bases found, all lead being calculated as litharge, antimony as pentasulphide, mercury as sulphide, magnesium as oxide, calcium as carbonate (or sulphate), zinc as oxide or sulphide, and barium as sulphate (rarely as carbonate).

To detect zinc sulphide a small amount of the original sample is warmed with hydrochloric acid. The evolution of hydrogen sulphide indicates the presence of zinc sulphide, carbon dioxide the presence of calcium or barium carbonate. In case all the barium is insoluble, it will be present as the sulphate, not as the carbonate.

The quantity of sulphur required to form the necessary sulphides of zinc, antimony, or mercury is found by calculation from the amount of each base present, and is taken as the figure for "sulphur in the inorganic constituents," which is deducted from the amount of sulphur in the residue left from the pyridine extraction to obtain the amount of sulphur of vulcanisation.

As a further control for the figures for sulphur, an estimation of the total sulphur in the original sample may be performed.

As is the case with all indirect determinations, the estimation of rubber by difference is liable to several errors, but these are of little practical consequence in *normal* samples. Moreover, all suggestions of direct methods for the determination of india-rubber, such as the formation of polyprene tetrabromide, have been found quite useless in practice.

## NOTES ON THE INTERPRETATION OF RESULTS.

*Acetone extract*: This important test is applied in practically every case, and is to be found embodied in the War Office specifications, as well as those of the leading railway and other companies.

The figures given by this test alone at once decide into which class to place the sample. The nature and quantity of the extract indicate immediately, although they do not exactly determine, the class of rubber used in the manufacture of the article under examination. In case the extract only contains rubber resins and free sulphur, it is usually of an oily or gummy nature, and may be washed from the crystals of sulphur with acetone, as previously described. The amount



of resin so obtained should then be calculated, in the first place on the total initial weight of the sample extracted, and also on the rubber proved subsequently to be present. This gives us a figure for "organic extract in india-rubber," and it is the restriction of this figure which is the object of the specifications relating to chemical tests on india-rubber. The War Office specifications for india-rubber will not accept a sample in which this figure exceeds 10 per cent., which excludes the use of medium and poor grade rubbers, as it is only such rubbers as Pará rubber, good plantation rubber, and especially good grades of Massai, and the like, which give so low a figure for the resin content. It may be claimed that Pará rubber only carries 3-4 per cent. of resin before manufacture, but it must be remembered that during mixing and vulcanisation the resin content of all rubbers increases; in some cases by as little as 2 per cent., in others by as much as 8 per cent. This discounts to a large extent the value of the conclusions drawn from this figure; on the other hand, it allows of general conclusions to be drawn on broad lines which may be of great assistance.

In case the extract contains resin oil, a characteristic blue fluorescence is noticeable in the extract, which will be of a dark colour. One of the best methods for detecting resin oil is Renard's reaction as given by Allen. The test reagent is stannic bromide, prepared by allowing bromine to fall drop by drop on granulated tin contained in a dry flask immersed in cold water. The addition is continued until the permanent coloration of the product shows that bromine is in excess. A further moderate addition of bromine is then made, and the liquid is diluted with three or four times its volume of carbon disulphide, in which the stannic bromide is readily soluble. To employ the reagent, which when thus prepared appears to be perfectly stable, a few drops of the sample to be tested should be placed in a dry test tube and dissolved in about 1 cc. of carbon disulphide. The bromide reagent is then gradually added, and if resin oil be present the liquid will rapidly acquire a fine violet coloration. In the presence of much mineral oil Allen finds it a good plan to first mix the sample of oil with a solution of stannic bromide in carbon disulphide, and then add, drop by drop, a solution of bromine in carbon disulphide, by which means a violet coloration is often to be obtained unobscured by any colour produced by the mineral oil. This colour is destroyed by the addition of alcohol, ether, ammonia, or water. Chloroform may be substituted for carbon disulphide in this test. Mineral oils impart a greenish fluorescence to the acetone solution during extraction, and may

be removed, together with all fatty oils (except castor oil) by washing out the other portions of the extract with alcohol, in which these oils are insoluble. By saponifying this oily residue, the fatty oils may be removed from the mineral oil. If no fatty substitutes be present the free oils in the extract must have been added to the mixing as such or in the form of reclaimed rubber (from which mineral oil can almost invariably be extracted).

If fatty substitutes be found, and the amount of free fatty oil does not exceed 15 per cent. of the amount of substitute present, it may be assumed that this oil is derived from the substitute, and has not been added as free oil to the mixing. Attention should be drawn to this point when presenting the report of analysis.

If such a sample is to be matched for manufacturing purposes, the substitute it is proposed to employ should be analysed, and any deficiency in free oil made up by addition of oil to the mixing. A substitute containing too much free oil must be discarded and replaced by one of lower oil content.

Any wax (paraffin wax or ozokerite) found in the extract may be estimated by warming with about 50 cc. glacial acetic acid, and allowing to cool, when the wax separates out. It is filtered off, washed with acetic acid, dissolved in carbon disulphide, evaporated to dryness in a weighed flask, and weighed.

*Pyridine extract*: Tar and pitch are often added to rubber mixings which contain low grade rubbers, or mixings carrying large amounts of "dry" matter, such as ground waste rubber or an excessive amount of mineral matter, with the object of facilitating the operation of mixing. They also reduce the porosity of the resultant goods and render them more inert to the influences of air, light, and chemical action. The use of asphaltum is confined to hard rubber goods. Although scarcely a point of chemical interest, it is still worthy of note that the majority of rubber goods received from America contain reclaimed rubber and "mineral rubber" (a black flexible tough substance partaking of the nature of both the waxes and the bitumens), while European samples often contain less of these ingredients and more fatty substitutes.

*Alcoholic potash extract*: The fatty substitutes saponified by this process may be oxidised oils, or chloro-sulphide substitutes in cold vulcanised goods, or sulphide substitutes with or without the other two in hot vulcanised goods. Sulphide substitutes are never used in cold vulcanised articles, and as cold vulcanisation by means of a 2 per cent. solution of sulphur monochloride in carbon disulphide can only be applied



to thin articles, any such goods which give a test which indicates the presence of sulphide substitutes must be regarded with suspicion. A more frequent error is the misrepresentation of the chloro-sulphide substitute present in hot vulcanised goods as sulphide substitute. This is due to the fact that during the process of vulcanisation the chlorine in this substitute is to a large extent evolved as hydrochloric acid, which is absorbed both by the mineral matter and the india-rubber, leaving the alcoholic potash extract almost free from chlorine. The chlorine will be found in the india-rubber, and may give rise to the impression that the goods have been "cold cured." That this is erroneous becomes obvious when the thickness of the goods is taken into consideration, for it is manifestly impossible to vulcanise valves, car tyres, hose, or buffers, by cold vulcanisation. It must also be remembered that sulphide substitutes are *never* used in "cold cured" articles.

*Nitronaphthalene extract*: By this means the amount of vulcanised rubber contained in the sample is estimated. This sample includes the new rubber, together with any reclaimed rubber, waste rubber, and balata which may have been added.

Since the rubber (of whatever kind) or balata is only present in the extract in the form of its decomposition products, it is impossible as yet to determine chemically which kind of rubber was originally employed, and no chemical means of detecting reclaimed rubber or balata have hitherto been devised. The presence of ground rubber waste may often be detected microscopically by examining the original sample under a  $\frac{1}{4}$ " objective, when a peculiar granular structure is revealed. This method is, however, not quantitative.

On calculating the "sulphur of vulcanisation" on the "india-rubber" present, a figure known as the "coefficient of vulcanisation" is obtained. Thus, a sample containing 60 per cent. of "india-rubber," and 3 per cent. of "sulphur of vulcanisation" would show a "coefficient of vulcanisation" of 5 per cent. With a mixture containing a definite quantity of new rubber, the higher the coefficient of vulcanisation, the harder will be the final article. If, however, a high coefficient of vulcanisation be found where the physical condition of the goods suggests a lower coefficient, then the presence of reclaimed rubber must be strongly suspected, since reclaimed rubbers, although softened by reclaiming, still contain their full quantity of combined sulphur, which thus increases the final "coefficient of vulcanisation." The presence of reclaimed rubber is further indicated by a high figure for "organic extract" in india-rubber (see *acetone extract*). In cases where

reclaimed rubber is present, mineral or resin oils are always found in the acetone extract.

*Water extract*: The presence of such organic fillers as starches is of such rare occurrence that this extraction is usually omitted, although it was of some importance before the introduction of the fatty substitutes.

*Inorganic constituents*: Although the detection and determination of these constituents offer little difficulty, it is often useful to know what minerals to expect in any particular grade of rubber. In "heat-resisting" rubbers, such as steam rubbers and jointings, litharge is nearly always present, as is also asbestos, talc, and often magnesia or lime. The majority of rubber mixings for mechanical goods contain zinc as oxide or sulphide, barium sulphate, and calcium carbonate. Rubber goods intended to withstand the action of acids do not contain carbonates or oxides (with the exception of litharge), and are usually filled with substitutes, mineral rubber, wax, and the silicates such as french chalk, asbestos, atmoid, together with barytes. The action of litharge and magnesium oxide being to accelerate vulcanisation and produce a harder and tougher product, they are often found in car tyres and other articles which are called upon to withstand mechanical abrasion.

In case traces of almost every mineral used by the manufacturer be found in a sample the presence of reclaimed or ground waste rubber should at once be suspected, since it is by those channels that many constituents occur in rubber goods entirely without the knowledge of the manufacturer.

## ANALYSIS OF TOBACCO.

S. E. HODGKINSON, A.I.C.

### BRITISH TOBACCO EXCISE REGULATION.

Tobacco is neither a food nor a drug, so its purity is not guarded by the Food and Drugs Act. It is, however, a very important source of revenue to the State, and very stringent regulations as to its purity and manufacture are stipulated by the Commissioners of Customs and Excise. It must not contain more than 32 per cent. of water nor more than 4 per cent. of oil. Further, it must not contain any ingredients other than tobacco, water, oil, essential oils (for flavouring), or acetic acid.

### TECHNICAL ASSAY OF TOBACCO.

Chemical analysis of tobacco is not of much assistance in arriving at a decision as to its quality, and as a consequence the only estimations usually made are those for water, oil, nicotine, inorganic matter and sand, which, other than nicotine, are required for legal purposes. For plant purposes the nicotine determination is the only one required; and Garner's method is to be recommended instead of the more accurate but lengthy A.O.A.C. official methods.

#### *Water.*

A known weight is dried at 100°C. for eight hours. Other substances than water are vaporised, but, from the wording of the moisture clause of the Revenue Act, these must be calculated as water.

#### *Oil.*

13.33 grm. of the tobacco, very finely divided, are macerated for twelve hours with 100 cc. of petroleum ether; 75 cc. (representing 10 grms. of tobacco) of the ethereal extract are drawn off, filtered if necessary, and placed in a tared flask. The ether is distilled off, and the residual extract dried at 100°C. for one hour and weighed. If the total extract is below 4.5 per cent., it may be assumed that the amount of oil is below 4 per cent. For this method to be considered accurate a determination of the amount of extractable matter in the leaf from which the tobacco was

manufactured would have to be made. Amounts varying from 2.9 to 4.5 per cent. of extractable matter have recently been obtained in two varieties of leaf as imported. Such values are, however, exceptional, the usual amount obtained from raw leaf being about 0.5 per cent. By the present method of analysis, manufactured tobacco sometimes gives a lower ether extract than the leaf from which it is made. A comparison of the saponification value of the ether extract with that of the oil used assists in obtaining an idea of the amount of added oil.

### *Inorganic Matter and Sand.*

The tobacco is first dried, and a definite weight incinerated over a small Bunsen flame. After all the "volatile carbon" has been expelled the incineration is completed in a muffle furnace at a dull red heat, cooled, and the ash moistened with a strong solution of ammonium carbonate, in order to recarbonate the free bases. It is then dried for eighteen hours and weighed.

### *Sand.*

The ash obtained as above is treated with hydrochloric acid (1:6) filtered, the residue dried, ignited and weighed. Another method is to treat the ash with concentrated hydrochloric acid, evaporate to dryness, heat to 150°C. for half an hour, treat with dilute hydrochloric acid (1:12), filter, dry the residue, ignite and weigh.

### *Nicotine.*

Many methods have been proposed for the estimation of nicotine, of varying degrees of reliability. (For a comparative study of six methods see J. Töth, *J.S.C.I.*, 1911, 1084.) Three methods are here described. (For other methods see Kissling, *Analyst*, 1904, 378; Bertrand and Javillier, *J.S.C.I.*, 1899, 404, *J.S.C.I.*, 1909, 326, *J.S.C.I.* 1911, 978; J. Töth, *Analyst*, 1912, 452; Schröder, *Analyst*, 1911, 106; Harrison and Self, *Pharm. J.*, 1912, 718; *J.C.S.*, 1922, ii, 404).

The following method is due to Garner (Bulletin No. 102 U.S. Bureau of Plant Industry, Washington, 1907). It appears to be a modification of one by Schloesing (described in Grandeau's *Agricultural Chemical Analysis*, Berlin, 1879). It is rapid and sufficiently accurate for technical purposes.

6 grm. of finely divided air-dried tobaccos are well mixed with 3 to 5 cc. of a 5 per cent. solution of caustic soda and transferred to a 250 cc. stoppered cylinder. Or the tobacco

may be mixed in the cylinder by means of a long glass rod. 100 cc. of petroleum ether are added, and vigorously shaken. The mixture is allowed to stand for four hours, the cylinder being laid on its side so as to expose a greater surface of tobacco to the action of the ether, shaking vigorously every 30 mins. After allowing the mixture to settle the clear extract is passed through a filter, 75 cc. of the filtrate, equal to 4.5 gm. tobacco being collected. This is allowed to stand in an open flask exposed to the air, for  $\frac{1}{2}$  hr., or air is drawn through it, to remove the ammonia, only a small proportion of which is extracted by the ether. It is next shaken in a separating funnel with 10 cc. N/5 sulphuric acid diluted to 50 cc. with water. The aqueous layer is drawn off, the petroleum spirit washed twice with a little water, and the excess of acid in the aqueous liquid titrated with N/10 alkali, using cochineal as indicator. 1 cc. N/5 acid is equal to 0.0324 gm. nicotine. The amount of water is determined in a corresponding sample, and the weight of tobacco taken corrected accordingly. The main difference of the above from Töth's method is that Töth recommends moistening the tobacco and mixing with plaster of Paris until the whole forms a dry powdery mass, the plaster of Paris retaining the ammonia. Toluene or xylene may be used as solvent.

The standard methods of the A.O.A.C. are the Kissling Method and the Silicotungstic Acid Method, described below.

*Kissling's Method for the determination of Nicotine.*

Weigh about 20 gm. of finely-powdered tobacco, which has been previously dried at 60°C. Add 10 cc. of alcoholic soda solution (6 gm. caustic soda, 40 cc. water and 60 cc. 90 per cent. alcohol) and mix thoroughly. Transfer to a Soxhlet extractor and exhaust for five hours with ether. Evaporate off the ether at a low temperature, and take up the residue with 50 cc. dilute caustic soda solution (4 gm. caustic soda in 1000 cc. of water). Transfer this residue by means of water to a Kjeldahl distillation apparatus, capable of holding about 500 cc., and distil in a current of steam, using a well-cooled condenser. A few pieces of pumice and a small piece of paraffin should be used to prevent bumping and frothing. Continue the distillation until all the nicotine has passed over, the distillate usually varying from 400 cc. to 500 cc. When the distillation is complete only about 15 cc. of the liquid should remain in the distillation flask. Titrate the distillate with N/10 sulphuric acid, using phenacetolin or cochineal as indicator. One molecule of sulphuric acid is equivalent to two molecules of nicotine.

*Silicotungstic Acid Method for the determination of Nicotine.*

Silicotungstic acid solution. Prepare a 12 per cent. solution of the silicotungstic acid having the following formula:  $4\text{H}_2\text{O}.\text{SiO}_2.12\text{WO}_3.22\text{H}_2\text{O}$ .

Sodium or potassium hydroxide solution (1 : 2), and dilute hydrochloric acid (1 : 4), are also necessary.

Weigh such an amount of the preparation as will contain preferably between 0.1 and 1.0 gm. of nicotine (if the sample contains very little nicotine, about 0.1 per cent., do not increase the amount to the point where it interferes with the distillation); wash with water into a 500 cc. round-bottomed distillation flask; add a small amount of paraffin to prevent frothing, a few small pieces of pumice and a slight excess of the sodium or potassium hydroxide, using phenolphthalein as an indicator. Steam distil rapidly through an efficient condenser connected, by means of an adapter, with a suitable flask containing 10 cc. of the dilute hydrochloric acid. When distillation is proceeding, heat the distillation flask to reduce the volume of the liquid as far as practicable without bumping or undue separation of insoluble matter. Distil until a few cc. of the distillate show no opalescence when treated with a drop of the silicotungstic acid and a drop of the dilute hydrochloric acid. Confirm the alkalinity of the residue in the distillation flask with phenolphthalein solution. Make up the distillate, which may amount to 1000—1500 cc. to a convenient volume (the solution may be concentrated on the steam-bath without loss of nicotine), mix well, and, if not clear, pass through a large dry filter. Test a portion with methyl orange to ensure its acidity. Pipette an aliquot portion, containing about 0.1 gm. of nicotine into a beaker (if the samples contain very small amounts of nicotine, an aliquot containing as little as 0.01 gm. of nicotine may be used), and add to each 100 cc. of liquid 3 cc. of the dilute hydrochloric acid, or more if the necessity is indicated by the test with methyl orange, and 1 cc. of the silicotungstic acid for each 0.01 gm. of nicotine supposed to be present. Stir thoroughly and allow to stand overnight. Before filtering, stir the precipitate to see that it settles quickly and is in crystalline form; then filter on an ashless filter, and wash with cold dilute hydrochloric acid (1 : 1000). Transfer the paper and precipitate to a weighed platinum crucible, dry carefully, and ignite until all carbon is removed. Finally, heat over a Téclu or Méker burner for not more than 10 mins. The weight of the residue, multiplied by 0.114, gives the weight of nicotine present in the aliquot portion.



# Percentage Composition of American Tobacco

Dried at 100°C. (G. E. Moore).

|   | Virginia<br>Sun-cured | Virginia<br>Flue-cured<br>low grade | Clarks-<br>ville<br>Fire-cured<br>Soil: heavy<br>rich loam | Kentucky<br>Air-cured | Perique | Wisconsin<br>Seed leaf |
|---|-----------------------|-------------------------------------|--|-----------------------|---------|------------------------|
|   | 1                     | 2                                   | 3  | 4                     | 5       | 6                      |
| Nicotine .....  | 3.26                  | 4.30                                | 5.29   | 3.12                  | 4.32    | 0.86                   |
| Resin and fats .....                                  | 4.15                  | 4.65                                | 4.99   | 5.34                  | 6.28    | 3.28                   |
| Starch .....  | 5.89                  | 2.75                                | 3.54   | 4.45                  | 2.45    | 4.15                   |
| Glucose .....   | 6.89                  | 2.75                                | 0.00   | 0.00                  | 0.00    | 0.00                   |
| Albuminoids (N. $\times$ 6.25) ..                     | 16.09                 | 13.66                               | 16.54  | 15.98                 | 15.80   | 20.34                  |
| Pectic (acid anhydride) ..                            | 6.19                  | 7.46                                | 6.01   | 7.49                  | 6.66    | 11.61                  |
| Citric ..   | 2.12                  | 2.84                                | 2.99   | 4.05                  | 1.18    | 2.99                   |
| Malic ..  | 5.02                  | 7.58                                | 5.51   | 9.26                  | 3.94    | 6.88                   |
| Oxalic ,  | 0.84                  | 1.03                                | 1.30   | 2.18                  | 3.49    | 1.07                   |
| Acetic ..   | 0.42                  | 0.55                                | 0.39   | 0.64                  | 1.62    | 0.68                   |
| Nitric ..   | 0.00                  | 0.00                                | 1.55   | 0.00                  | 0.00    | 1.22                   |
| Ammonia .....   | 0.33                  | 0.32                                | 0.98   | 0.48                  | 0.76    | 0.63                   |
| Crude fibre .....                                     | 9.58                  | 9.24                                | 9.68   | 12.18                 | 9.08    | 12.97                  |
| Sand .....  | 0.55                  | 2.38                                | 2.25   | 0.66                  | 4.17    | 1.53                   |
| Ash (exclusive of sand<br>and CO <sub>2</sub> ) ..... | 12.41                 | 13.36                               | 14.37  | 16.06                 | 13.30   | 15.43                  |
| Undetermined .....                                    | 26.26                 | 27.13                               | 24.61  | 18.11                 | 26.95   | 16.36                  |

## ASH ANALYSES.

|   | Virginia<br>Sun-cured | Virginia<br>Flue-cured<br>low grade | Clarks-<br>ville<br>Fire-cured<br>Soil: heavy<br>rich loam | Kentucky<br>Air-cured | Wisconsin<br>Seed leaf |
|---|-----------------------|-------------------------------------|--|-----------------------|------------------------|
| Total Ash .....                                       | 14.29                 | 17.42                               | 19.23  | 21.85                 | 20.81                  |
| Ash (exclusive of sand<br>and CO <sub>2</sub> ) ..... | 12.41                 | 13.36                               | 14.37  | 16.06                 | 15.43                  |
| Potash .....  | 34.16                 | 26.55                               | 33.15  | 39.51                 | 38.71                  |
| Soda .....  | 0.26                  | 0.22                                | 0.15   | 0.86                  | 1.08                   |
| Lime .....  | 31.76                 | 36.96                               | 36.48  | 39.80                 | 33.49                  |
| Magnesia .....  | 7.91                  | 11.51                               | 11.85  | 5.34                  | 12.57                  |
| Ferric oxide .....                                    | 0.58                  | 0.95                                | 0.51   | 1.56                  | 0.79                   |
| Alumina .....   | 1.22                  | 1.81                                | 0.95   | 0.51                  | 0.74                   |
| Manganous oxide .....                                 | 0.00                  | 0.00                                | 0.25   | 0.13                  | trace                  |
| Phosphoric anhydride ..                               | 3.81                  | 3.23                                | 4.42   | 6.09                  | 3.09                   |
| Sulphuric ..  | 4.99                  | 4.27                                | 6.16   | 4.52                  | 3.89                   |
| Silicic ..  | 1.39                  | 3.29                                | 3.42   | 1.20                  | 4.65                   |
| Chlorine .....  | 13.92                 | 11.21                               | 2.66   | 0.48                  | 0.99                   |



# CHEMICAL INVENTIONS AND THE LAW OF PATENTS.

H. E. PORTS, M.Sc., Chartered Patent Agent.

In order to obtain the best results from the patent system, it is desirable that chemists should become familiar with some of the leading features of patent law. All that can be done here is to indicate some of the chief points of interest, and to explain why the chemist should give them his attention.

## 1. *Patents or Secret Processes.*

Many chemists do not realise that processes can be protected, and that infringement can be prevented, even though competitors might try to use the process unlawfully. Apart from the possibility of leakage of information, it is possible in appropriate cases to obtain an order for inspection of the defendant's works by independent experts, or the Court may order the defendant to answer questions termed "interrogatories." Infringement actions have been successful where the defendants used the patented process abroad, or alleged that they had a process of their own which was so secret that the Court heard the evidence *in camera*.

The objection that infringers will escape by making some slight modification of the patented process is based on an erroneous conception of the scope of a patent, which, if skilfully drafted, prevents such modifications.

Secret working suffers from the grave dangers that the monopoly is entirely lost if the secret leaks out, and that others may independently discover the secret, and even patent it. This will entail loss of foreign rights, and may cause serious inconvenience in the United Kingdom. In fact, if one firm has developed a process but not used it *commercially*, another party may well obtain a valid patent preventing the first firm from proceeding further.

The research chemist will find that patents are more negotiable than secret processes, and once a process has been patented, publication of his research work can be made safely, with advantage to his professional standing.

## 2. *What can be patented?*

It is best for the chemist to forget preconceived ideas, and to accept the dogmatic statement that, in effect, the majority of new and useful improvements are patentable. The Patent Office will grant a patent for any new variation of an existing process, and *a fortiori*, for any new process; if such a variation or process is not obvious, and possesses substantial advantages in practice, the Court would probably hold the patent valid. Thus patents can be obtained—

- (a) to protect a new reaction broadly, as applied to a useful purpose;
- (b) to protect combinations of known steps giving a new result, *e.g.*, lustring cotton by combining the old steps of treatment with caustic soda and stretching;
- (c) to protect variations in detail in an existing process, *e.g.*, the discovery that mercerisation can be effected with advantage at some particular concentration of caustic soda, although the literature contains general statements as to ranges of concentration including the new concentration;
- (d) to protect the application of a known process to homologues if the result could not have been definitely foreseen; thus a dyestuff patent may cover the extension of an existing process to alkyl derivatives of a known intermediate.

In all these cases, a specific improvement is not anticipated by mere vague statements in the literature which would not lead a skilled chemist to the desired result unless he had been taught by the patentee. Mere analogy is not conclusive ground of anticipation in chemical patents. If it is discovered that a certain catalyst gives good results in the reduction of phenol to cyclo-hexanol, it would not be legitimate to argue that this was not patentable merely because—

- (i) it was known that phenol could be reduced catalytically to cyclo-hexanol; and
- (ii) it was known that the particular catalyst could be used for other reactions.

Catalytic phenomena are so specific and difficult to predict that a patent would certainly be allowed if the particular catalyst had never been used *for this reaction*, and if the results were favourable, the Court would probably sustain the patent.

A novel improvement can be patented, even though it infringes an existing patent. Infringement and anticipation are different issues.

### 3. *Requirements as to inventorship.*

The original inventor must appear as one of the applicants for a British patent (unless it is filed as a communication from abroad or under the International Convention): other names, including the name of a firm, may be added. The law as to the rights of joint applicants is complex, and it is advisable for both chemist and employer that their respective rights should be defined by an equitable agreement.

A patent application must be filed before the invention has been "published": the term publication includes oral communication to parties not under the bond of secrecy. The application ought to be made if possible before the invention is used commercially, *i.e.*, in the works as distinct from the laboratory. Indeed, it is desirable to obtain provisional protection at the earliest possible date to avoid risk of leakage or independent invention by competitors.

### 4. *Patent applications.*

Although a complete specification may be filed in the first instance, it is nearly always advisable to file a provisional specification, because this procedure gives a period of nine months' protection in which the invention can be further developed.

The provisional specification ought to describe the invention as fully as possible, but it need not be as detailed as a complete specification, and it can contain a forecast of future work,—to be elaborated in detail before the complete specification is filed.

In preparing a provisional specification, care should be taken to forestall possible evasions by competitors, and the protection should not be limited to a mere recital of optimum conditions, although if the specification is correctly drafted it is advisable to give optimum conditions without limiting protection to those conditions only.

It is often unwise to delay filing a provisional specification until the process has been successful on a large scale, or until commercial possibilities are favourable. If the nine months is not sufficient to develop the invention, the provisional specification can be abandoned, and in this case it is *not* published, so that a fresh provisional specification can be filed giving a further nine months' protection, but with the loss of the original priority; or the matter can then be kept entirely secret.

During the period of provisional protection, in addition to the work required to convert a laboratory process into a

large scale process, it is also desirable to develop the theory of the process, and to investigate possible variations, such as those foreshadowed in the provisional specification. Care should also be taken to verify all experimental data, and to give examples of the process which will be sufficient to enable a skilled chemist to obtain some beneficial result.

There should be a full and frank discussion between chemist and patent agent at all stages in the prosecution of the application.

After the complete specification has been filed, the Patent Office issues a report which gives the results of the official search, and draws attention to any points as to which amendment may be necessary. The cited publications and these objections must be carefully considered; the specification must be amended, or suitable arguments must be filed to overcome the official objections. This action on the part of the Patent Office usually strengthens the patent, if adequate attention is given to the preparation of a reply—which should not usually consist in a mere cancellation of the passages to which objection is raised, or a mere statement that the examiner's objections are irrelevant.

### *5. Scope of patents.*

While a single important patent occasionally dominates an entire field of industry, it usually happens that the original patentees buttress their position by subsidiary patents, which will assist in extending the practical monopoly beyond the life of the original patent. It is also important to obtain protection for possible modifications of the original process as they are discovered, because although these modifications may not be superior in any way, the patents will deter competitors by blocking research in parallel directions.

On the other hand, if the competitor himself has patents it must not be hastily assumed that his position is impregnable. The patents may be invalid, or it may be possible to devise efficient modifications which will not infringe. The field covered by the patents should therefore be thoroughly surveyed, in the light of a full knowledge of the relevant literature, to ascertain whether there are any loopholes, and if so, research should then be pursued along the lines indicated by this survey.

### *6. Patents abroad.*

Important chemical inventions are usually protected in France, Germany and U.S.A. if possible, although other

countries are often important. The British patent does not cover the Empire, and a Canadian patent is often desirable if the invention is to be worked in U.S.A.

In Germany, the Patent Office makes a very thorough search for novelty among the scientific literature and patent specifications of the world. The examiners reject a patent if they consider the process is obvious to the skilled chemist. It is therefore necessary to bring forward any arguments which show that the result obtained by the invention is contrary to expectation, or that the result is characteristic in some striking way; arguments of a theoretical nature are often successful, but sometimes reports by acknowledged expert chemists are helpful.

The German law allows patents for chemical processes, but not for purely chemical products, although these are protected by the patent if made by the patented process. Entirely different methods of making the new product are not protected.

In U.S.A. the examination for novelty is fairly extensive, but the standard is not usually so rigid as in Germany. The broadest claims can be obtained for chemical products as such, however prepared, and claims are even allowed for known substances of a certain high degree of purity as shown by a M.P. higher than that ever recorded previously. The preparation of claims is governed by a highly elaborate and artificial system of rules which cannot be briefly summarized.

# NOTABLE DATES IN THE HISTORY OF CHEMISTRY.

|  |            |
|--|------------|
|  | B.C.       |
| <i>Thales.</i> Water, the Element of the World.  | 640-550    |
| <i>Pythagoras.</i> Mass.   | 582-500    |
| <i>Anaximenes.</i> Air, the World Principle.   | circa 550  |
| <i>Empedocles.</i> Four principles: Fire, water, air, earth.   | 492-432    |
| <i>Hippocrates.</i> Recognised and employed 230 species of plants as medicines.  | 460-377    |
| <i>Democritus</i> , creator, with Leucippus, of the Atomic theory.   | 460-370    |
| <i>Theophrastus.</i> Recognised 500 plants. Mineralogy. Prepared white lead and litharge.  | 390-286    |
| <i>Aristoteles.</i> Matter, form and motion.   | 384-322    |
| <i>Archimedes.</i> Principle of the lever; hydrostatics.   | 287-212    |
|  | A.D.       |
| <i>Dioskorides</i> , recognised 600 herbs, wrote " <i>De materia medica</i> ,"   | 50         |
| <i>Caius Plinius Secundus.</i> Author of " <i>Historia naturalis</i> ,"  | 79         |
| <i>Zosimos</i> of Panopolis (Egypt) used the word <i>χημία</i> or <i>χημεία</i> to indicate the art of making gold and silver about                      | 250        |
| <i>Djafar</i> or <i>Geber.</i> Discovered aqua fortis, aqua regia, lapis infernalis, and sublimate; also the processes of distillation, cupellation etc. | 702-765    |
| <i>Rhases.</i> Recognised vitriol, alcohol. Born in  | 932        |
| <i>Avicenna.</i> Medicinal and mineralogical papers. (Rocks, metals, sulphur compounds and salts.)   | 980-1037   |
| <i>Albertus Magnus.</i> Founder of Alchemy.  | 1193-1280  |
| <i>Roger Bacon.</i> Methods of research in natural science; mirrors, magnifying glass; doubted transmutation of metals.                                  | 1214-1294  |
| <i>Raymundus Lullius.</i> Prepared nitric acid, " <i>aqua prima</i> ."   | 1235-1315  |
| <i>Basil Valentine.</i> Antimony salts. Prepared hydrochloric acid, " <i>currus triumphalis antimonii</i> ,"   | 1413       |
| <i>Eck</i> noted increase in weight of metals on calcination, and oxygen; " <i>Theatrum chymicum</i> ,"  | 1489       |
| <i>Georg Agricola.</i> Mineralogy and metallurgy, " <i>De re metallica libri xii</i> ."  | 1490-1555  |
| <i>Paracelsus.</i> Iatrochemistry, application of chemistry to medicines.  | 1493-1541  |
| <i>Leonardo da Vinci</i> , noted artist, published his " <i>Codex Atlanticus</i> ," containing a correct view of combustion,                             | circa 1500 |



|  |           |
|--|-----------|
| <i>van Helmont</i> . Correct views on gases and flame, discovered carbon dioxide, first used the word "gas."   | 1572-1644 |
| <i>Zacharias Jansen</i> constructed microscope,  | 1590      |
| <i>Libarius</i> . Published "Alchemia," first text-book on chemistry,  | 1595      |
| <i>Galilei</i> constructed the thermometer,  | 1597      |
| <i>William Gilbert</i> . "De magnete magneticisque corporibus et de magno magnete tellure Phisologia nova," 1600, stated difference between "magnetism" and what he was the first to term "electricity." | 1540-1603 |
| <i>Galilei</i> . Pendulum and laws of falling bodies,  | 1602      |
| <i>Lippershey</i> constructed telescope,   | 1608      |
| <i>Napier</i> . Logarithms,  | 1614      |
| <i>William Harvey</i> discovered circulation of the blood,   | 1619      |
| <i>Francis Bacon</i> (1561-1626). Inductive method of research. "Novum organum."   | 1620      |
| <i>Robert Boyle</i> . Founded methods of chemical analysis.  | 1626-1691 |
| <i>Kepler</i> constructed astronomical telescope,  | 1630      |
| <i>Torricelli</i> and <i>Viviani</i> constructed barometer,  | 1633      |
| <i>René Descartes</i> (1596-1650). "Principia philosophiæ,"  | 1644      |
| <i>Pierre Gassendi</i> (1592-1655). Atomic theory,   | 1650      |
| <i>Blaise Pascal</i> (1623-1662). Researches on Atmospheric pressure,  | 1650      |
| <i>D. R. Glauber</i> (1603-1668). Discovered sodium sulphate in "de natura salium,"  | 1658      |
| <i>Boyle's Law</i> ( <i>Mariotte</i> , 1676) stated in   | 1662      |
| <i>Brand</i> discovered phosphorus,  | 1669      |
| <i>Mayow</i> published correct view of combustion in "de Sale Nitro et Siphritu Nitroæro,"   | 1669      |
| <i>Lemery</i> (1645-1715) considered five elements: mercury or spirit, sulphur or oil, salt (active), water or phlegma, and earth (passive principles); published "Cours de Chymie,"                     | 1675      |
| <i>Isaac Newton</i> (1643-1727) stated law of gravitation in "Philosophiæ naturalis Principia mathematica,"  | 1687      |
| <i>Huygens</i> (1629-1695) published the wave theory of light in "Traité de la lumière,"   | 1690      |
| <i>Stahl</i> (1660-1734) developed the Phlogiston theory in "Zymotechnia fundamentalis,"   | 1697      |
| <i>Boettger</i> (1685-1719) discovered porcelain   | 1703      |
| <i>Leeuwenhoek</i> (1632-1723) recognised blood corpuscles, infusoria, spermatozoa, etc.,  | 1720      |
| <i>Fahrenheit</i> (1686-1736) suggested scale for thermometry,   | 1724      |



|  |      |
|--|------|
| <i>Réaumur</i> (1693–1757) suggested scale for thermometry,  | 1730 |
| <i>Linné</i> (1707–1778) founded his botanical system in "Systema naturæ,"   | 1735 |
| <i>Celsius</i> (1701–1744) suggested scale for thermometry, known in England as Centigrade,  | 1740 |
| <i>Brandt</i> (1694–1768) isolated cobalt,   | 1743 |
| Zinc manufactured on a large scale at Bristol,   | 1743 |
| <i>Roebuck</i> erected first lead chamber for sulphuric acid manufacture at Preston Pans,  | 1746 |
| <i>Marggraff</i> (1709–1783) discovered sugar in beetroot,   | 1747 |
| <i>Antonio de Ulloa</i> (1716–1795) described platinum in "Relacion de viage a la America meridional,"                             | 1748 |
| <i>Cronstedt</i> (1702–1756) isolated nickel,  | 1751 |
| <i>Black</i> (1728–1799) stated the difference between caustic and carbonated alkalies, investigated specific heat of water, etc., | 1755 |
| <i>Watt</i> (1736–1819) invented the steam engine,   | 1769 |
| <i>Priestley</i> (1733–1804) discovered oxygen and ammonia,  | 1774 |
| <i>Scheele</i> (1742–1786) discovered chlorine ("dephlogistigated marine acid gas"),   | 1774 |
| <i>Scheele</i> discovered oxygen, 1773, published discovery,   | 1775 |
| <i>Lavoisier</i> (1743–1794) found composition of air ("oxygène"); theory of combustion,   | 1775 |
| <i>Gahn</i> (1745–1818) isolated manganese,  | 1775 |
| <i>Bergmann</i> (1735–1784) decomposed oxalic acid into carbon dioxide and carbon monoxide,  | 1775 |
| <i>Scheele</i> discovered glycerin,  | 1779 |
| <i>Scheele</i> discovered hydrocyanic acid,  | 1782 |
| <i>Hjelm</i> (1746–1813) isolated molybdenum,  | 1782 |
| <i>Fausto d'Elhuyar</i> (1755–1832) discovered tungsten,   | 1783 |
| <i>Cavendish</i> (1731–1810) discovered hydrogen; synthesised water,   | 1784 |
| <i>Cort</i> used puddling process in manufacture of iron,  | 1784 |
| <i>Klaproth</i> (1743–1817) discovered uranium and the zirconium earths,   | 1789 |
| <i>Berthollet</i> (1748–1822) introduced bleaching powder,   | 1789 |
| <i>Leblanc</i> discovered method for manufacture of soda (details first published in 1797),  | 1791 |
| <i>Richter</i> (1762–1807) stated law of definite proportions in "Anfangsgründe der Stöchiometrie,"                                | 1792 |
| <i>Klaproth</i> discovered titanium,   | 1795 |
| <i>Berzelius</i> discovered zirconium,   | 1795 |
| <i>Lampadius</i> (1772–1842) discovered carbon disulphide,   | 1796 |
| <i>Vauquelin</i> (1763–1829) discovered chromium,  | 1797 |
| <i>Klaproth</i> discovered tellurium,  | 1798 |

|   |      |
|---|------|
| <i>Thompson, Rumford</i> (1753-1814). Researches on mechanical equivalent of heat,  | 1798 |
| <i>Murdoch</i> (1754-1839) introduced coal gas as illuminant at the works of Boulton and Watt,                                  | 1798 |
| <i>Volta</i> (1745-1827) discovered the electrometer, 1788; the eudiometer, 1790; and Volta's pile,                             | 1800 |
| <i>Achard</i> (1753-1821) erected first beet sugar works,   | 1801 |
| <i>Haüy</i> (1743-1822) suggested crystallographic system in "Traité de la Minéralogie,"  | 1801 |
| <i>Gay Lussac's Law</i> stated in   | 1802 |
| <i>Proust</i> (1755-1826) discovered grape sugar,   | 1802 |
| <i>Berthollet</i> published "Essai de statique chimique"  | 1803 |
| <i>Wollaston</i> (1766-1828) discovered palladium and rhodium.  | 1804 |
| <i>Tennant</i> (1761-1815) discovered osmium and iridium,   | 1804 |
| <i>Sertürner</i> isolated the first alkaloid, morphine,   | 1805 |
| <i>Gay-Lussac</i> and <i>Humboldt</i> determined the composition of water by volume,  | 1805 |
| <i>Dalton</i> (1766-1844) suggested law of multiple proportions and the atomic theory in "A new system of chemical philosophy," | 1806 |
| <i>Davy</i> (1778-1829) isolated metals from the alkalies and alkaline earths,  | 1808 |
| <i>Gay-Lussac</i> (1778-1850) stated law of combination of gases by volume,   | 1808 |
| <i>Malus</i> (1775-1812) discovered polarisation of light,  | 1808 |
| <i>Berzelius</i> isolated (amorphous) silicon,  | 1810 |
| <i>Avogadro</i> (1776-1856) stated his hypothesis,  | 1811 |
| <i>Kirchhoff</i> discovered the conversion of starch into sugar,  | 1811 |
| <i>Courtois</i> discovered iodine,  | 1812 |
| <i>Fraunhofer</i> determined the lines in the solar spectrum,   | 1814 |
| <i>Gay-Lussac</i> discovered cyanogen,  | 1815 |
| <i>Stromeyer</i> (1776-1835) discovered cadmium,  | 1817 |
| <i>Berzelius</i> discovered selenium,   | 1817 |
| <i>Thenard</i> (1777-1857) discovered hydrogen peroxide,  | 1818 |
| <i>Fuchs</i> prepared water-glass,  | 1818 |
| <i>Arfvedson</i> (1792-1841) discovered lithium,  | 1818 |
| <i>Vicat</i> (1786-1861) first prepared an artificial cement,   | 1818 |
| <i>Berzelius</i> (1779-1848) suggested the electrochemical theory,  | 1819 |
| <i>Dulong</i> (1785-1838) and <i>Petit's law</i> ,  | 1819 |
| <i>Mitscherlich</i> (1794-1863) discovered isomorphism,   | 1820 |
| <i>Pelletier</i> and <i>Caventou</i> isolated quinine,  | 1820 |
| <i>Oersted</i> (1777-1851) discovered electromagnetism,   | 1820 |
| <i>Döbereiner</i> (1780-1849) prepared aldehyde (examined and so named by <i>Liebig</i> ),                                      | 1821 |
| <i>Ampère</i> (1775-1836) founded electrodynamics,  | 1822 |

|   |      |
|---|------|
| <i>Schützenbach</i> invented quick vinegar process,   | 1823 |
| <i>Aspdin</i> prepared Portland cement,   | 1824 |
| <i>Unverdorben</i> prepared aniline by distillation of Indigo,  | 1826 |
| <i>Chevreul</i> (1786–1889), researches on fats,  | 1826 |
| <i>Balard</i> discovered bromine,   | 1826 |
| <i>Wöhler</i> discovered aluminium, 1827; beryllium,  | 1828 |
| <i>Gmelin</i> prepared ultramarine,   | 1828 |
| <i>Berzelius</i> discovered thorium,  | 1828 |
| <i>Niepce</i> and <i>Daquerre</i> discovered photographic process (published, 1839),                          | 1829 |
| <i>Wöhler</i> synthesised urea,   | 1829 |
| <i>Sefström</i> discovered vanadium,  | 1830 |
| <i>Liebig</i> (also <i>Soubeirin</i> ) prepared chloroform,   | 1831 |
| <i>Liebig</i> and <i>Wöhler</i> investigated benzoyl compounds, advanced the radical theory,                  | 1832 |
| <i>Faraday</i> stated laws of electrolysis,   | 1833 |
| <i>Graham</i> , researches on phosphoric acid,  | 1833 |
| <i>Zeise</i> prepared mercaptan,  | 1833 |
| <i>Runge</i> isolated aniline and phenol from coal-tar,   | 1834 |
| <i>Mitscherlich</i> discovered nitrobenzene,  | 1834 |
| <i>Dumas</i> and <i>Péligot</i> , researches on methyl alcohol,   | 1835 |
| <i>Jacoby</i> discovered electro-plating,   | 1836 |
| <i>Schwann</i> , researches on fermentation and decay,  | 1837 |
| <i>Laurent</i> and <i>Gerhardt</i> suggested theory of types,   | 1837 |
| <i>Dumas</i> (1800–1884) prepared trichloroacetic acid; suggested theory of types,                            | 1839 |
| <i>Regnault</i> (1810–1878), ethylene and ethylene chloride; specific heat of simple and compound substances, | 1839 |
| <i>Hess's</i> law stated in   | 1840 |
| <i>Liebig</i> published "Chemie in ihrer Anwendung auf Agrikultur und Physiologie,"                           | 1840 |
| <i>Fritzsche</i> prepared aniline by distilling Indigo with caustic potash,                                   | 1840 |
| <i>Goodyear</i> first vulcanised rubber (also <i>Hancock</i> , 1843),   | 1840 |
| <i>Zinin</i> prepared aniline by reduction of nitrobenzene,   | 1842 |
| <i>Schönbein</i> prepared ozone,  | 1842 |
| <i>Claus</i> discovered ruthenium,  | 1845 |
| <i>Schrötter</i> investigated red phosphorus,   | 1845 |
| <i>Schönbein</i> (also <i>Böttger</i> , and <i>Otto</i> ) discovered gun-cotton,                              | 1845 |
| <i>Wurtz</i> (also <i>Hofmann</i> ) prepared substituted derivatives of ammonia,                              | 1849 |
| <i>Hofmann</i> isolated benzene from coal-tar, 1845; carried out on a large scale by <i>Mansfield</i> ,       | 1849 |
| <i>Kolbe</i> , researches on the electrolysis of organic compounds,   | 1849 |

|   |      |
|---|------|
| <i>Bunsen</i> , experiments on cacodyl and the theory of radicals,                          | 1850 |
| <i>Graham</i> , diffusion of liquids,   | 1850 |
| <i>Frankland</i> , theory of "atomicity" of elements; discovered organo-metallic compounds, | 1852 |
| <i>Williamson</i> , theory of the formation of ethers,                                      | 1852 |
| <i>Thomsen</i> published "Grundzüge eines thermo-chemischen Systems,"                       | 1853 |
| <i>Pasteur</i> split tartaric acid into optical isomerides,                                 | 1853 |
| <i>Berthelot</i> , glycerin a "triatomic" alcohol,  | 1853 |
| <i>Wurtz</i> (also <i>Buff</i> ) prepared the "diatomic" alcohol, glycol,                   | 1856 |
| <i>Wöhler</i> and <i>St. Claire Deville</i> prepared boron,                                 | 1856 |
| <i>Perkin</i> prepared aniline violet or mauve,   | 1856 |
| <i>Bessemer</i> introduced his converter,   | 1856 |
| <i>St. Claire Deville</i> , researches on dissociation,                                     | 1857 |
| <i>Siemens</i> introduced regenerative gas furnace,   | 1857 |
| <i>Pasteur</i> commenced researches on fermentation and micro-organisms,                    | 1858 |
| <i>Kekulé</i> noted the tetratomicity of carbon,  | 1858 |
| <i>Hofmann</i> commenced researches on aniline colours,                                     | 1858 |
| <i>Verguin</i> prepared Rosaniline (Magenta) on a large scale at Lyons,                     | 1859 |
| <i>Darwin</i> published "Origin of species,"  | 1859 |
| <i>Kirchhoff</i> and <i>Bunsen</i> introduced spectrum analysis,                            | 1859 |
| <i>Kirchhoff</i> and <i>Bunsen</i> discovered rubidium and cæsium,                          | 1861 |
| <i>Crookes</i> discovered thallium,   | 1861 |
| <i>Glover</i> introduced tower into sulphuric acid manufacture at Wallsend, near Newcastle, | 1861 |
| <i>Solvay</i> successfully carried out ammonia-soda process,                                | 1861 |
| <i>Frank</i> (also <i>Grüneberg</i> ) founded Stassfurt potash industry,                    | 1861 |
| <i>Robert</i> introduced diffusion process in manufacture of beetroot sugar,                | 1863 |
| <i>Reich</i> and <i>Richter</i> discovered indium,  | 1863 |
| <i>St. Claire Deville</i> , researches on dissociation,                                     | 1864 |
| <i>Geuther</i> prepared aceto-acetic ether,   | 1864 |
| <i>Fittig</i> and <i>Tollens</i> synthesised aromatic hydrocarbons,                         | 1864 |
| <i>Delafontaine</i> discovered erbium and terbium,  | 1865 |
| <i>Berthelot</i> published "Leçons sur la Thermo-chimie,"                                   | 1865 |
| <i>Kekulé</i> introduced benzene theory,  | 1865 |
| <i>Guldberg</i> and <i>Waage</i> , chemical equilibrium and law of mass action,             | 1867 |
| <i>Roscoe</i> recognised vanadium as an element,  | 1867 |
| <i>Weldon</i> introduced regenerative process for manganese dioxide,                        | 1867 |

|  |           |
|--|-----------|
| <i>Graebe and Liebermann</i> prepared Alizarin from anthracene,                                    | 1868      |
| <i>Fremy and Gore</i> prepared pure hydrofluoric acid,   | 1869      |
| <i>Nobel</i> introduced nitroglycerin into explosives (discovered by <i>Sombrero</i> , 1847),      | 1869      |
| <i>Mendeleeff</i> , also <i>L. Meyer</i> ( <i>Newlands</i> , 1864), stated Periodic Law,           | 1869      |
| <i>Hyatt</i> invented celluloid  | 1869      |
| <i>Le Bel</i> and <i>van't Hoff</i> , asymmetric carbon atom,                                      | 1875      |
| <i>Lecoq de Boisbaudran</i> discovered gallium,  | 1875      |
| <i>Cailletet</i> , also <i>Pictet</i> , liquefied oxygen, hydrogen, etc.,                          | 1877      |
| <i>Perkin</i> prepared cinnamic acid, etc.,  | 1877      |
| <i>Gibbs</i> , phase rule  | 1877      |
| <i>E. and O. Fischer</i> proved that the Rosaniline dyestuffs are derivatives of triphenylmethane, | 1878      |
| <i>Baeyer</i> synthesised Indigo,  | 1878      |
| <i>Remsen</i> discovered saccharin   | 1879      |
| <i>Nilsson</i> discovered scandium,  | 1880      |
| <i>Raoult</i> , experiments on the depression of the freezing-point in equimolecular solutions,    | 1882      |
| <i>Winkler</i> discovered germanium,   | 1886      |
| <i>Moissan</i> isolated fluorine,  | 1886      |
| <i>Welsbach</i> introduced incandescent light,   | 1886      |
| <i>van't Hoff</i> , theory of solution and osmotic pressure,                                       | 1886      |
| <i>Arrhenius</i> , theory of electrolytic dissociation,  | 1887      |
| <i>van't Hoff</i> and <i>Wislicenus</i> , stereochemical theory,                                   | 1887      |
| <i>Baeyer</i> investigated formula of benzene,   | 1888-1890 |
| <i>E. Fischer</i> synthesised carbohydrates, 1887, and dextrose,                                   | 1890      |
| <i>Acheson</i> invented carborundum  | 1891      |
| <i>Vidal</i> prepared the first Sulphur black,   | 1893      |
| <i>Willson</i> , technical application of calcium carbide (discovered by <i>Wöhler</i> , 1862),    | 1894      |
| <i>Rayleigh</i> and <i>Ramsay</i> discovered argon and helium.                                     | 1894      |
| <i>Acheson</i> discovered synthetic graphite   | 1895      |
| <i>Röntgen</i> , researches on X-rays,   | 1895      |
| <i>Frank and Caro</i> prepared cyanides and cyanamides from carbides and atmospheric nitrogen,     | 1895      |
| <i>Curie</i> , also <i>Becquerel</i> , radioactivity and radium,                                   | 1898      |
| <i>E. Fischer</i> synthesised purine,  | 1898      |
| Contact process for sulphuric acid introduced,   | 1899      |
| <i>Ramsay and Travers</i> isolated krypton, xenon, and neon,                                       | 1900      |
| <i>Grignard</i> , syntheses by means of organic magnesium compounds,                               | 1901      |
| <i>Bohn</i> prepared indanthrene,  | 1901      |
| <i>Birkeland and Eyde</i> prepared nitric acid from the air,                                       | 1905      |

# CHEMICAL AND OTHER SCIENTIFIC JOURNALS.

| Year. | Ann. (Lieb.) | Ann. chim. | Amer. C.J. | Amer. J.Sci. | Analyst. | Ann. Min. | Ber. | Bull. S.chim. | Chem. Gaz. | Chem. News | Chem. Ztg. | Chem. Zentr. | Compt. rend. | Dingl. polyt. | Gazz. ch.it. | J.Amer. C.S. |
|-------|--------------|------------|------------|--------------|----------|-----------|------|---------------|------------|------------|------------|--------------|--------------|---------------|--------------|--------------|
| 1850  | 73-76        | 28-30      | ...        | 6, 10        | ...      | 17, 18    | ...  | ...           | ...        | ...        | ...        | 21           | 30, 31       | 115-118       | ...          | ...          |
| 1851  | 77-80        | 31-33      | ...        | 11, 12       | ...      | 19, 20    | ...  | ...           | ...        | ...        | ...        | 22           | 32, 33       | 119-122       | ...          | ...          |
| 1852  | 81-84        | 34-36      | ...        | 13, 14       | ...      | (5) 1, 2  | ...  | ...           | ...        | ...        | ...        | 23           | 34, 35       | 123-126       | ...          | ...          |
| 1853  | 85-88        | 37-39      | ...        | 15, 16       | ...      | 3, 4      | ...  | ...           | ...        | ...        | ...        | 24           | 36, 37       | 127-130       | ...          | ...          |
| 1854  | 89-92        | 40-42      | ...        | 17, 18       | ...      | 5, 6      | ...  | ...           | ...        | ...        | ...        | 25           | 38, 39       | 131-134       | ...          | ...          |
| 1855  | 93-96        | 43-45      | ...        | 19, 20       | ...      | 7, 8      | ...  | ...           | ...        | ...        | ...        | 26           | 40, 41       | 135-138       | ...          | ...          |
| 1856  | 97-100       | 46-48      | ...        | 21, 22       | ...      | 9, 10     | ...  | ...           | ...        | ...        | ...        | 27           | 42, 43       | 139-142       | ...          | ...          |
| 1857  | 101-104      | 49-51      | ...        | 23, 24       | ...      | 11, 12    | ...  | ...           | ...        | ...        | ...        | 28           | 44, 45       | 143-146       | ...          | ...          |
| 1858  | 105-108      | 52-54      | ...        | 25, 26       | ...      | 13, 14    | ...  | ...           | ...        | ...        | ...        | 29           | 46, 47       | 147-150       | ...          | ...          |
| 1859  | 109-112      | 55-57      | ...        | 27, 28       | ...      | 15, 16    | ...  | ...           | ...        | ...        | ...        | 30           | 48, 49       | 151-154       | ...          | ...          |
| 1860  | 113-116      | 58-60      | ...        | 29, 30       | ...      | 17, 18    | ...  | ...           | ...        | ...        | ...        | 31           | 50, 51       | 155-158       | ...          | ...          |
| 1861  | 117-120      | 61-63      | ...        | 31, 32       | ...      | 19, 20    | ...  | ...           | ...        | ...        | ...        | 32           | 52, 53       | 159-162       | ...          | ...          |
| 1862  | 121-124      | 64-66      | ...        | 33, 34       | ...      | (6) 1, 2  | ...  | ...           | ...        | ...        | ...        | 33           | 54, 55       | 163-166       | ...          | ...          |
| 1863  | 125-128      | 67-69      | ...        | 35, 36       | ...      | 3, 4      | ...  | ...           | ...        | ...        | ...        | 34           | 56, 57       | 167-170       | ...          | ...          |
| 1864  | 129-132      | (4) 1-3    | ...        | 37, 38       | ...      | 5, 6      | ...  | ...           | ...        | ...        | ...        | 35           | 58, 59       | 171-174       | ...          | ...          |
| 1865  | 133-136      | 4-6        | ...        | 39, 40       | ...      | 7, 8      | ...  | ...           | ...        | ...        | ...        | 36           | 60, 61       | 175-178       | ...          | ...          |
| 1866  | 137-140      | 7-9        | ...        | 41, 42       | ...      | 9, 10     | ...  | ...           | ...        | ...        | ...        | 37           | 62, 63       | 179-182       | ...          | ...          |
| 1867  | 141-144      | 10-12      | ...        | 43, 44       | ...      | 11, 12    | ...  | ...           | ...        | ...        | ...        | 38           | 64, 65       | 183-186       | ...          | ...          |
| 1868  | 145-148      | 13-15      | ...        | 45, 46       | ...      | 13, 14    | ...  | ...           | ...        | ...        | ...        | 39           | 66, 67       | 187-190       | ...          | ...          |
| 1869  | 149-152      | 16-18      | ...        | 47, 48       | ...      | 15, 16    | ...  | ...           | ...        | ...        | ...        | 40           | 68, 69       | 191-194       | ...          | ...          |
| 1870  | 153-156      | 19-21      | ...        | 49, 50       | ...      | 17, 18    | ...  | ...           | ...        | ...        | ...        | 41           | 70, 71       | 195-198       | ...          | ...          |
| 1871  | 157-160      | 22-24      | ...        | (3) 1, 2     | ...      | 19, 20    | ...  | ...           | ...        | ...        | ...        | 42           | 72, 73       | 199-202       | ...          | ...          |
| 1872  | 161-164      | 25-27      | ...        | 3, 4         | ...      | (7) 1, 2  | ...  | ...           | ...        | ...        | ...        | 43           | 74, 75       | 203-206       | ...          | ...          |
| 1873  | 165-170      | 28-30      | ...        | 5, 6         | ...      | 3, 4      | ...  | ...           | ...        | ...        | ...        | 44           | 76, 77       | 207-210       | ...          | ...          |
| 1874  | 171-174      | (5) 1-3    | ...        | 7, 8         | ...      | 5, 6      | ...  | ...           | ...        | ...        | ...        | 45           | 78, 79       | 211-214       | ...          | ...          |
| 1875  | 175-179      | 4-6        | ...        | 9, 10        | ...      | 7, 8      | ...  | ...           | ...        | ...        | ...        | 46           | 80, 81       | 215-218       | ...          | ...          |
| 1876  | 180-183      | 7-9        | ...        | 11, 12       | ...      | 9, 10     | ...  | ...           | ...        | ...        | ...        | 47           | 82, 83       | 219-222       | ...          | ...          |
| 1877  | 184-189      | 10-12      | ...        | 13, 14       | ...      | 11, 12    | ...  | ...           | ...        | ...        | ...        | 48           | 84, 85       | 223-226       | ...          | ...          |
| 1878  | 190-191      | 13-15      | ...        | 15, 16       | ...      | 13, 14    | ...  | ...           | ...        | ...        | ...        | 49           | 86, 87       | 227-230       | ...          | ...          |
| 1879  | 195-199      | 16-18      | ...        | 17, 18       | ...      | 15, 16    | ...  | ...           | ...        | ...        | ...        | 50           | 88, 89       | 231-234       | ...          | ...          |
| 1880  | 200-205      | 19-21      | ...        | 19, 20       | ...      | 17, 18    | ...  | ...           | ...        | ...        | ...        | 51           | 90, 91       | 235-238       | ...          | ...          |



| Year. | J.C.S. Trans. | J. pr. Chem. | J. Russ. Soc. | Monat. f. Chem. | Mon. Sci. | Nature. | Phil. Mag. | Phil. Trans. | Proc. Roy. Soc. | Wien. Sitzber. | Zanal. Chem. |
|-------|---------------|--------------|---------------|-----------------|-----------|---------|------------|--------------|-----------------|----------------|--------------|
| 1850  | 3             | 49-51        | ..            | ..              | ..        | ..      | 36, 37     | 140          | ..              | 4, 5           | ..           |
| 1851  | 4             | 52-54        | ..            | ..              | ..        | ..      | (4) 1, 2   | 141          | 5               | 6, 7           | ..           |
| 1852  | 5             | 55-57        | ..            | ..              | ..        | ..      | 3, 4       | 142          | ..              | 8, 9           | ..           |
| 1853  | 6             | 58-60        | ..            | ..              | ..        | ..      | 5, 6       | 143          | ..              | 10, 11         | ..           |
| 1854  | 7             | 61-63        | ..            | ..              | ..        | ..      | 7, 8       | 144          | 6               | 12-14          | ..           |
| 1855  | 8             | 64-66        | ..            | ..              | ..        | ..      | 9, 10      | 145          | ..              | 15-18          | ..           |
| 1856  | 9             | 67-69        | ..            | ..              | ..        | ..      | 11, 12     | 146          | ..              | 19-21          | ..           |
| 1857  | 10            | 70-72        | ..            | ..              | ..        | ..      | 13, 14     | 147          | 8               | 22-27          | ..           |
| 1858  | 11            | 73-75        | ..            | (1) 1           | ..        | ..      | 15, 16     | 148          | ..              | 28-33          | ..           |
| 1859  | 12            | 76-78        | ..            | 2               | ..        | ..      | 17, 18     | 149          | 9               | 34-38          | ..           |
| 1860  | 13            | 79-81        | ..            | 3               | ..        | ..      | 19, 20     | 150          | 10              | 39-42          | ..           |
| 1861  | 14            | 82-84        | ..            | 4               | ..        | ..      | 21, 22     | 151          | ..              | 43             | ..           |
| 1862  | 15            | 85-87        | ..            | ..              | ..        | ..      | 23, 24     | 152          | ..              | 44, 45         | ..           |
| 1863  | 16            | 88-90        | ..            | ..              | ..        | ..      | 25, 26     | 153          | 11              | 46-48          | ..           |
| 1864  | 17            | 91-93        | ..            | 5               | ..        | ..      | 27, 28     | 154          | 12              | 49             | ..           |
| 1865  | 18            | 94-96        | ..            | (2) 6           | ..        | ..      | 29, 30     | 155          | 13              | 50-52          | ..           |
| 1866  | 19            | 97-99        | ..            | 7               | ..        | ..      | 31, 32     | 156          | 14              | 53, 54         | ..           |
| 1867  | 20            | 100-102      | ..            | 8               | ..        | ..      | 33, 34     | 157          | ..              | 55, 56         | ..           |
| 1868  | 21            | 103-105      | ..            | 9               | ..        | ..      | 35, 36     | 158          | 15              | 57, 58         | ..           |
| 1869  | 22            | 106-108      | ..            | 10              | ..        | ..      | 37, 38     | 159          | 16              | 59, 60         | ..           |
| 1870  | 23            | (2) 1, 2     | 1             | 11              | ..        | 1, 2    | 39, 40     | 160          | 17              | 61, 62         | ..           |
| 1871  | 24            | 3, 4         | 2             | 12              | ..        | 3, 4    | 41, 42     | 161          | 18              | 63, 64         | ..           |
| 1872  | 25            | 5, 6         | 3             | (3) 13          | ..        | 5, 6    | 43, 44     | 162          | 19              | 65, 66         | ..           |
| 1873  | 26            | 7, 8         | 4             | 14              | ..        | 7, 8    | 45, 46     | 163          | 20              | 67, 68         | ..           |
| 1874  | 27            | 9, 10        | 5             | 15              | ..        | 9, 10   | 47, 48     | 164          | 21              | 69, 70         | ..           |
| 1875  | 28            | 11, 12       | 6             | 16              | ..        | 11, 12  | 49, 50     | 165          | 22              | 71, 72         | ..           |
| 1876  | 29, 30        | 13, 14       | 7             | 17              | ..        | 13, 14  | (5) 1, 2   | 166          | 23              | 73, 74         | ..           |
| 1877  | 31, 32        | 15, 16       | 8             | 18              | ..        | 15, 16  | 3, 4       | 167          | 24              | 75, 76         | ..           |
| 1878  | 33, 34        | 17, 18       | 9             | 19              | ..        | 17, 18  | 5, 6       | 169          | 25, 26          | 77, 78         | ..           |
| 1879  | 35, 36        | 19, 20       | 10            | 20              | ..        | 19, 20  | 7, 8       | 170, 168     | 27              | 79, 80         | ..           |
| 1880  | 37, 38        | 21, 22       | 11            | 21              | ..        | 21, 22  | 9, 10      | 171          | 28, 29          | 81, 82         | ..           |
|       |               |              | 12            | 22              | ..        |         |            |              | 30              |                | ..           |



CHEMICAL AND OTHER SCIENTIFIC JOURNALS—continued.

| Year. | Ann. (Lieb.) | Ann. chim. | Amer. C.J. | Amer. J.Sci. | Analyst. | Ann. Min. | Ber. | Bull. S.chim. | Chem. News. | Chem. Ztg. | Chem. Centr. | Compt. rend. | Dingl. polyt. | Gaz. ch. it. | J. Amer. C.S. |
|-------|--------------|------------|------------|--------------|----------|-----------|------|---------------|-------------|------------|--------------|--------------|---------------|--------------|---------------|
| 1881  | 206-210      | 22-24      | 3          | 21, 22       | 9        | 19, 20    | 14   | 35, 36        | 43, 44      | 5          | 52           | 92, 93       | 239-242       | 11           | 3             |
| 1882  | 211-215      | 25-27      | 4          | 23, 24       | 7        | (8) 1, 2  | 15   | 37, 38        | 45, 46      | 6          | 53           | 94, 95       | 243-246       | 12           | 4             |
| 1883  | 216-221      | 28-30      | 5          | 25, 26       | 8        | 3, 4      | 16   | 39, 40        | 47, 48      | 7          | 54           | 96, 97       | 247-250       | 13           | 5             |
| 1884  | 222-226      | (6) 1-3    | 6          | 27, 28       | 9        | 5, 6      | 17   | 41, 42        | 49, 50      | 8          | 55           | 98, 99       | 251-254       | 14           | 6             |
| 1885  | 227-231      | 4-6        | 7          | 29, 30       | 10       | 7, 8      | 18   | 43, 44        | 51, 52      | 9          | 56           | 100, 101     | 255-258       | 15           | 7             |
| 1886  | 232-236      | 7-9        | 8          | 31, 32       | 11       | 9, 10     | 19   | 45, 46        | 53, 54      | 10         | 57           | 102, 103     | 259-262       | 16           | 8             |
| 1887  | 237-242      | 10-12      | 9          | 33, 34       | 12       | 11, 12    | 20   | 47, 48        | 55, 56      | 11         | 58           | 104, 105     | 263-266       | 17           | 9             |
| 1888  | 243-249      | 13-15      | 10         | 35, 36       | 13       | 13, 14    | 21   | 49, 50        | 57, 58      | 12         | 59           | 106, 107     | 267-270       | 18           | 10            |
| 1889  | 250-255      | 16-18      | 11         | 37, 38       | 14       | 15, 16    | 22   | 51, 52        | 59, 60      | 13         | 60           | 108, 109     | 271-274       | 19           | 11            |
| 1890  | 256-260      | 19-21      | 12         | 39, 40       | 15       | 17, 18    | 23   | 53, 54        | 61, 62      | 14         | 61           | 110, 111     | 275-278       | 20           | 12            |
| 1891  | 261-266      | 22-24      | 13         | 41, 42       | 16       | 19, 20    | 24   | 55, 56        | 63, 64      | 15         | 62           | 112, 113     | 279-282       | 21           | 13            |
| 1892  | 266-271      | 25-27      | 14         | 43, 44       | 17       | (9) 1, 2  | 25   | 57, 58        | 65, 66      | 16         | 63           | 114, 115     | 283-286       | 22           | 14            |
| 1893  | 272-277      | 28-30      | 15         | 45, 46       | 18       | 3, 4      | 26   | 59, 60        | 67, 68      | 17         | 64           | 116, 117     | 287-290       | 23           | 15            |
| 1894  | 278-283      | (7) 1-3    | 16         | 47, 48       | 19       | 5, 6      | 27   | 61, 62        | 69, 70      | 18         | 65           | 118, 119     | 291-294       | 24           | 16            |
| 1895  | 281-288      | 4-6        | 17         | 49, 50       | 20       | 7, 8      | 28   | 71, 72        | 71, 72      | 19         | 66           | 120, 121     | 295-298       | 25           | 17            |
| 1896  | 289-293      | 7-9        | 18         | (4) 1, 2     | 21       | 9, 10     | 29   | 73, 74        | 73, 74      | 20         | 67           | 122, 123     | 299-302       | 26           | 18            |
| 1897  | 294-298      | 10-12      | 19         | 3, 4         | 22       | 11, 12    | 30   | 75, 76        | 75, 76      | 21         | 68           | 124, 125     | 303-306       | 27           | 19            |
| 1898  | 299-303      | 13-15      | 20         | 5, 6         | 23       | 13, 14    | 31   | 77, 78        | 77, 78      | 22         | 69           | 126, 127     | 307-310       | 28           | 20            |
| 1899  | 301-309      | 16-18      | 21         | 7, 8         | 24       | 15, 16    | 32   | 79, 80        | 79, 80      | 23         | 70           | 128, 129     | 311-314       | 29           | 21            |
| 1900  | 310-313      | 19-21      | 22         | 9, 10        | 25       | 17, 18    | 33   | 81, 82        | 81, 82      | 24         | 71           | 130, 131     | 315           | 30           | 22            |
| 1901  | 314-319      | 22-24      | 23         | 11, 12       | 26       | 19, 20    | 34   | 83, 84        | 83, 84      | 25         | 72           | 132, 133     | 316           | 31           | 23            |
| 1902  | 320-325      | 25-27      | 24         | 13, 14       | 27       | (10) 1, 2 | 35   | 85, 86        | 85, 86      | 26         | 73           | 134, 135     | 317           | 32           | 24            |
| 1903  | 326-329      | 28-30      | 25         | 15, 16       | 28       | 3, 4      | 36   | 87, 88        | 87, 88      | 27         | 74           | 136, 137     | 318           | 33           | 25            |
| 1904  | 330-337      | (8) 1-3    | 26         | 17, 18       | 29       | 5, 6      | 37   | 89, 90        | 89, 90      | 28         | 75           | 138, 139     | 319           | 34           | 26            |
| 1905  | 338-343      | 4-6        | 27         | 19, 20       | 30       | 7, 8      | 38   | 91, 92        | 91, 92      | 29         | 76           | 140, 141     | 320           | 35           | 27            |
| 1906  | 344-350      | 7-9        | 28         | 21, 22       | 31       | 9, 10     | 39   | 93, 94        | 93, 94      | 30         | 77           | 142, 143     | 321           | 36           | 28            |
| 1907  | 351-357      | 10-12      | 29         | 23, 24       | 32       | 11, 12    | 40   | (4) 1, 2      | 95, 96      | 31         | 78           | 144, 145     | 322           | 37           | 29            |
| 1908  | 358-363      | 13-15      | 30         | 25, 26       | 33       | 13, 14    | 41   | 5, 6          | 97, 98      | 32         | 79           | 146, 147     | 323           | 38           | 30            |
| 1909  | 364-371      | 16-18      | 31         | 27, 28       | 34       | 15, 16    | 42   | 7, 8          | 99, 100     | 33         | 80           | 148, 149     | 324           | 39           | 31            |
| 1910  | 372-377      | 19-21      | 32         | 29, 30       | 35       | 17, 18    | 43   | 9, 10         | 101, 102    | 34         | 81           | 150, 151     | 325           | 40           | 32            |
| 1911  | 378-385      | 22-24      | 33         | 31, 32       | 36       | 19, 20    | 44   | 11, 12        | 103, 104    | 35         | 82           | 152, 153     | 326           | 41           | 33            |
| 1912  | 386-394      | 25-27      | 34         | 33, 34       | 37       | (11) 1, 2 | 45   | 13, 14        | 105, 106    | 36         | 83           | 154, 155     | 327           | 42           | 34            |
| 1913  | 395-401      | 28-30      | 35         | 35, 36       | 38       | 3, 4      | 46   | 15, 16        | 107, 108    | 37         | 84           | 156, 157     | 328           | 43           | 35            |

| Year. | J.C.S. Trans. | J. pr. Chem. | J. Russ. Soc. | J. Soc. C. Ind. | J. Soc. Dyers | Monat. f. Chem. | Mon. Sci. | Nature. | Phil. Mag. | Phil. Trans. | Proc. Roy. Soc. | Wien. Sitzber. | Z. anal. Chem. | Z. angew. Chem. | Z. anorg. Chem. | Z. Chem. Ind. Koll. | Z. phys. Chem. | Chem. Abstr. | Zeitsch. f. Elektrochem. |
|-------|---------------|--------------|---------------|-----------------|---------------|-----------------|-----------|---------|------------|--------------|-----------------|----------------|----------------|-----------------|-----------------|---------------------|----------------|--------------|--------------------------|
| 1881  | 39, 40        | 22, 24       | 13            | 1               | ...           | 2               | 23        | 23, 24  | 11, 12     | 172          | 31, 32          | 83, 84         | 20             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1882  | 41, 42        | 25, 26       | 14            | 1               | ...           | 3               | 24        | 25, 26  | 13, 14     | 173          | 33              | 85, 86         | 21             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1883  | 43, 44        | 27, 28       | 15            | 2               | ...           | 4               | 25        | 27, 28  | 15, 16     | 174          | 34, 35          | 87, 88         | 22             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1884  | 45, 46        | 29, 30       | 16            | 3               | ...           | 5               | 26        | 29, 30  | 17, 18     | 175          | 36, 37          | 89, 90         | 23             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1885  | 47, 48        | 31, 32       | 17            | 4               | 1             | 9               | 27        | 31, 32  | 19, 20     | ...          | 38, 39          | 91, 92         | 24             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1886  | 49, 50        | 33, 34       | 18            | 5               | 2             | 7               | 28        | 33, 34  | 21, 22     | 176          | 40, 41          | 93, 94         | 25             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1887  | 51, 52        | 35, 36       | 19            | 6               | 3             | 8               | (B) 1     | 35, 36  | 23, 24     | 177          | 42, 43          | 95, 96         | 26             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1888  | 53, 54        | 37, 38       | 20            | 7               | 4             | 10              | 2         | 37, 38  | 25, 26     | 178          | 44, 45          | 97             | 27             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1889  | 55, 56        | 39, 40       | 21            | 8               | 5             | 11              | 3         | 39, 40  | 27, 28     | 179          | 46, 47          | 99             | 28             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1890  | 57, 58        | 41, 42       | 22            | 9               | 6             | 12              | 4         | 41, 42  | 29, 30     | 180          | 48, 49          | 100            | 29             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1891  | 59, 60        | 43, 44       | 23            | 10              | 7             | 13              | 5         | 43, 44  | 31, 32     | 181          | 50              | 100            | 30             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1892  | 61, 62        | 45, 46       | 24            | 11              | 8             | 14              | 6         | 45, 46  | 33, 34     | 182          | 51, 52          | 101            | 31             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1893  | 63, 64        | 47, 48       | 25            | 12              | 9             | 15              | 7         | 47, 48  | 35, 36     | 183          | 53, 54          | 102            | 32             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1894  | 65, 66        | 49, 50       | 26            | 13              | 10            | 16              | 8         | 49, 50  | 37, 38     | 184          | 55, 56          | 103            | 33             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1895  | 67, 68        | 51, 52       | 27            | 14              | 11            | 17              | 9         | 51, 52  | 39, 40     | 185          | 57, 58          | 104            | 34             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1896  | 69, 70        | 53, 54       | 28            | 15              | 12            | 18              | 10        | 53, 54  | 41, 42     | 186, 188     | 59              | 105            | 35             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1897  | 71, 72        | 55, 56       | 29            | 16              | 13            | 19              | 11        | 55, 56  | 43, 44     | 187, 189     | 60, 61          | 106            | 36             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1898  | 73, 74        | 57, 58       | 30            | 17              | 14            | 20              | 12        | 57, 58  | 45, 46     | 190, 191     | 62, 63          | 107            | 37             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1899  | 75, 76        | 59, 60       | 31            | 18              | 15            | 21              | 13        | 59, 60  | 47, 48     | 192          | 64, 65          | 108            | 38             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1900  | 77, 78        | 61, 62       | 32            | 19              | 16            | 22              | 14        | 61, 62  | 49, 50     | 193, 194     | 66, 67          | 109            | 39             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1901  | 79, 80        | 63, 64       | 33            | 20              | 17            | 23              | 15        | 63, 64  | (6) 1, 2   | 195-197      | 68              | 110            | 40             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1902  | 81, 82        | 65, 66       | 34            | 21              | 18            | 24              | 16        | 65, 66  | 3, 4       | 198, 199     | 69, 70          | 111            | 41             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1903  | 83, 84        | 67, 68       | 35            | 22              | 19            | 25              | 17        | 67, 68  | 5, 6       | 200, 201     | 71              | 112            | 42             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1904  | 85, 86        | 69, 70       | 36            | 23              | 20            | 26              | 18        | 69, 70  | 7, 8       | 202, 203     | 72, 73          | 113            | 43             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1905  | 87, 88        | 71, 72       | 37            | 24              | 21            | 27              | 19        | 71, 72  | 9, 10      | 204, 205     | 74-76           | 114            | 44             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1906  | 89, 90        | 73, 74       | 38            | 25              | 22            | 28              | 20        | 73, 74  | 11, 12     | 206          | (A) 77          | 115            | 45             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1907  | 91, 92        | 75, 76       | 39            | 26              | 23            | 29              | 21        | 75, 76  | 13, 14     | ...          | 78, 79          | 116            | 46             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1908  | 93, 9         | 77, 78       | 40            | 27              | 24            | 30              | 22        | 77, 78  | 15, 16     | 207, 208     | 80, 81          | 117            | 47             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1909  | 95, 9         | 79, 80       | 41            | 28              | 25            | 31              | 23        | 79-81   | 17, 18     | 209          | 82              | 118            | 48             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1910  | 97, 98        | 81, 82       | 42            | 29              | 26            | 32              | 24        | 82-84   | 19, 20     | ...          | 83              | 119            | 49             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1911  | 99, 100       | 83, 84       | 43            | 30              | 27            | 33              | 25        | 85-87   | 21, 22     | 210          | 84, 85          | 120            | 50             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1912  | 101, 102      | 85, 86       | 44            | 31              | 28            | 34              | 26        | 88, 89  | 23, 24     | 211          | 86, 87          | 121            | 51             | ...             | ...             | ...                 | ...            | ...          | ...                      |
| 1913  | 103, 104      | 87, 88       | 45            | 32              | 29            | 35              | 27        | 90, 91  | 25, 26     | 212          | 88              | 122            | 52             | ...             | ...             | ...                 | ...            | ...          | ...                      |

## CONVERSION TABLES FOR WEIGHTS AND MEASURES.

- The Regulations of the Board of Trade (March, 1907) state :
- "The YARD is the length at 62°F. marked on a bronze bar deposited with the Board of Trade.
  - "The POUND is the weight of a piece of platinum weighed in *vacuo* at 0°C. which is deposited with the Board of Trade.
  - "The GALLON contains 10 lbs. weight of distilled water weighed in air against brass weights, with the water and the air at the temperature of 62°F., the barometer being at 30 inches.
  - "The METRE is the length, at the temperature of 0°C., of the iridio-platinum bar, numbered 16, deposited with the Board of Trade.
  - "The KILOGRAMME is represented by the iridio-platinum weight, numbered 18, deposited with the Board of Trade.
  - "The LITRE is represented by the capacity at 0°C. of the cylindrical brass measure, marked 'Litre, 1897' (which is deposited with the Board of Trade)."

The legalised fundamental equivalents are as follows :

|              |   |                   |
|--------------|---|-------------------|
| 1 Kilogramme | = | 15432·3564 grains |
| 1 Metre      | = | 39·370113 inches  |
| 1 Gallon     | = | 4·5459631 litres  |

---

Circular No. 47 of the U.S. Bureau of Standards states :—

- A METER (m) is a unit of length equivalent to the distance between the defining lines on the international prototype meter at the International Bureau of Weights and Measures when this standard is at 0°C.
- A YARD (yd.) is a unit of length equivalent to  $\frac{3600}{3937}$  of a meter.
- A LITER (l) is a unit of capacity equivalent to the volume occupied by the mass of 1 kilogram of pure water at its maximum density (at a temperature of 4°C, practically) and under the standard atmospheric pressure of 760 mm.). It is equivalent in volume to 1·000 027 decimeters.
- A GALLON (gal.) is a unit of capacity equivalent to the volume of 231 cubic inches.

A KILOGRAM (kg) is a unit of mass equivalent to the mass of the international prototype kilogram at the International Bureau of Weights and Measures.

An AVOIRDUPOIS POUND (lb. av.) is a unit of mass equivalent to 0.453 592 427 7 kilogram.

## Linear Measures.

|                       |                 | Log. of factor. |
|-----------------------|-----------------|-----------------|
| 1 inch                | 2.5400 cm.      | 0.40483         |
| 1 link (=7.92 inches) | 20.117 cm.      | 1.30356         |
| 1 foot (=12 inches)   | 30.480 cm.      | 1.48401         |
| 1 yard (=3 feet)      | 91.440 cm.      | 1.96114         |
| 1 pole (=5½ yards)    | 5.0292 metres   | 0.70150         |
| 1 chain (=100 links)  | 20.117 metres   | 1.30356         |
| 1 furlong (=40 poles) | 201.17 metres   | 2.30356         |
| 1 mile (=8 furlongs)  | 1609.34 metres  | 3.20665         |
| 1 centimetre          | 0.39370 inches  | ī.59517         |
| 1 metre               | 3.2808 feet     | 0.51598         |
|                       | or 1.0936 yards | 0.03886         |
| 1 kilometre           | 0.62137 mile    | ī.79335         |

1 micron ( $\mu$ ) = 0.000001 metre = 0.001 millimetre

1 millimicron ( $m \mu$ ) = 0.001 micron.

## Superficial Measures.

|                              |                           | Log. of factor.           |
|------------------------------|---------------------------|---------------------------|
| 1 sq. in.                    | 6.4516 sq. cm.            | 0.80967                   |
| 1 sq. ft. (=144 sq. ins.)    | 929.03 sq. cm.            | 2.96803                   |
| 1 sq. yd. (=9 sq. ft.)       | 8361.26 sq. cm.           | 3.92228                   |
| 1 acre (=4840 sq. yds.)      | 4046.85 sq. metres        | 3.60712                   |
|                              | or 40.4685 ares           | 1.60712                   |
| 1 sq. mile (=640 acres)      | 25899.8 ares              | 4.41330                   |
|                              | or 2.58998 sq. kilometres | 0.41330                   |
| 1 sq. cm.                    | 0.15500 sq. in.           | Log. of factor<br>1.19033 |
| 1 sq. m.                     | 1550.0 sq. in.            | 3.19033                   |
|                              | or 10.764 sq. ft.         | 1.03197                   |
|                              | or 1.1960 sq. yds.        | 0.07773                   |
| 1 are (dkm <sup>2</sup> )    | 119.60 sq. yds.           | 2.07773                   |
| 1 hectare (hm <sup>2</sup> ) | 2.4711 acres              | 0.39289                   |
| 1 sq. km.                    | 0.38610 sq. m.            | ī.58670                   |

## Cubical Measures.

|                                       |                         | Log. of factor. |
|---------------------------------------|-------------------------|-----------------|
| 1 c. in.                              | 16.387 cc.              | 1.21450         |
| 1 c. ft. (=1728 c. in.)               | 28316 cc                | 4.45203         |
| 1 c. yd. (=27 c. ft.)                 | 0.76455 c.m. (or stere) | 1.88341         |
| 1 cc.                                 | 0.061024 c. in.         | 2.78550         |
| 1 litre                               | 0.035315 c. ft.         | 2.54796         |
| 1 stere or c.m.                       | 35.315 c. ft.           | 1.54796         |
|                                       | or 1.30795 c. yds.      | 0.11659         |
| 1 cu. ft. of water weighs 62.335 lbs. |                         |                 |

## Measures of Capacity.

| Imperial units.             | Metric units.      | Log. of factor |
|-----------------------------|--------------------|----------------|
| 1 minim (m)                 | 0.059192 cc.       | 2.77226        |
| 1 fluid scruple             | 1.1838 cc.         | 0.07327        |
| 1 fluid drachm (=60 minims) | 3.5515 cc          | 0.55041        |
| 1 fluid ounce (fl. 3)       | 28.412 cc.         | 1.45350        |
| 1 gill (=5 fl. oz.)         | 0.14206 litres     | 1.15247        |
| 1 pint (=4 gills)           | 0.56825 litres     | 1.75454        |
| 1 gallon (=8 pints)         | 4.5460 litres      | 0.65763        |
| 1 peck (=2 gallons)         | 9.0919 litres      | 0.95865        |
| 1 bushel (=4 pecks)         | 36.368 litres      | 1.56072        |
| 1 quarter (=8 bushels)      | 290.94 litres      | 2.46380        |
| Metric units.               | Imperial units.    | Log. of factor |
| 1 cc.                       | 0.0070392 gills    | 3.84752        |
| 1 litre                     | 1.7598 pints       | 0.24547        |
|                             | or 0.21998 gallons | 1.34239        |
| 1 decalitre                 | 1.0999 pecks       | 0.04136        |
| 1 hectolitre                | 2.7497 bushels     | 0.43928        |

1 Imperial gallon of water weighs 10 lbs. and occupies 0.1604 cu. ft.

*Measures of Capacity used in B.P., 1914.*

|                         |                                |
|-------------------------|--------------------------------|
| 1 centimil (C)          | = 0.01 cc. = 0.169 minims.     |
| 1 decimil (D)           | = 0.1 cc. = 1.69 minims        |
| 1 millilitre or mil (M) | = 1 cc. = 16.9 minims.         |
| 1 litre (Lit)           | = 1000 cc. = 35.195 fluid ozs. |

## U.S. Measures of Capacity.

Log. of factor.

|                           |                     |         |
|---------------------------|---------------------|---------|
| 1 minim (min. or m)       | 0.06161 millilitres | 2.78965 |
| 1 fluid dram (60 minims)  | 3.6966 „            | 0.56780 |
| 1 fluid ounce (8 fl. dr.) | 29.573 „            | 1.47089 |
| 1 gill (4 fl. oz.)        | 0.11829 litres      | 1.07295 |
| 1 pint (4 gills)          | 0.47317 „           | 1.67501 |
| 1 quart (2 pints)         | 0.94633 „           | 1.97604 |
| 1 gallon (4 quarts)       | 3.78533 „           | 0.57811 |
| 1 dry pint                | 0.5506 „            | 1.74084 |
| 1 dry quart (2 dry pints) | 1.1012 „            | 0.04187 |
| 1 peck (8 dry quarts)     | 8.810 „             | 0.94498 |
| 1 bushel (4 pecks)        | 0.35238 hectolitres | 1.54701 |
| 1 cubic centimetre        | 0.27051 fluid drams | 1.43219 |
| 1 millimetre              | 0.27052 „           | 1.43220 |
| 1 litre                   | 2.1134 pints        | 0.32498 |
|                           | or 0.26418 gallons  | 1.42190 |
| 1 decalitre               | 2.6418 „            | 0.42190 |
| 1 hectolitre              | 26.418 „            | 1.42190 |

1 U.S. gallon of water weighs 8.33 lbs. and occupies 0.1336 cu. ft.

## Relations of British and American Units.

- 1 U.S. gallon=0.83268 Imperial gallon
- 1 U.S. bushel=0.96945 Imperial bushel
- 1 Imperial gallon=1.20094 U.S. gallon
- 1 Imperial bushel=1.03151 U.S. bushel
- 1 British gallon ale or beer=1.2208 U.S. gallon
- Barrel (British) or tierce=42 gallons
- Barrel (U.S. liquid, oil, etc.)=31.5 gallons

## Measures of Weight.

|                                  |                     | Log. of factor. |
|----------------------------------|---------------------|-----------------|
| 1 grain                          | 0.064799 grm.       | 2.81157         |
| 1 dram (avoir)                   | 1.7718 grm.         | 0.24842         |
| 1 ounce „                        | 28.3495 grm.        | 1.45255         |
| 1 pound „                        | 453.5924 grm.       | 2.65666         |
| 1 stone „                        | 6.3505 kgm.         | 0.80279         |
| 1 quarter „                      | 12.7006 kgm.        | 1.10382         |
| 1 short hundredweight (100 lbs.) | 45.3592 kgm.        | 1.65666         |
| 1 long „ (112 lbs.)              | 50.8024 kgm.        | 1.70588         |
| 1 short ton (2000 lbs.)          | 0.90718 metric tons | 1.95770         |
| 1 long „ (2240 lbs.)             | 1.01605 metric tons | 0.00691         |

|                               |                           | Log. of factor. |
|-------------------------------|---------------------------|-----------------|
| 1 scruple (apoth.)            | 1.2960 grm.               | 0.11260         |
| 1 pennyweight (troy)          | 1.5552 grm.               | 0.19179         |
| 1 drachm (℥) (apoth.)         | 3.8879 grm.               | 0.58971         |
| 1 ounce (℥) (troy and apoth.) | 31.103 grm.               | 1.49280         |
| 1 pound (troy and apoth.)     | 373.24 grm.               | 2.57199         |
| 1 metric carat (0.2 grm.)     | 3.0865 grains             | 0.48947         |
| 1 gramme                      | 15.432 grains             | 1.18843         |
|                               | or 0.56438 drams (avoir.) | 1.75157         |
|                               | or 0.035274 oz. (avoir.)  | 2.54746         |
| 1 kilogramme                  | 2.2046 lbs.               | 0.34333         |
| 1 metric ton                  | 0.98420 ton               | 1.99308         |

## Signs used for Medical Prescriptions.

|                       |                            |                     |                      |
|-----------------------|----------------------------|---------------------|----------------------|
| $\frac{1}{2}$ grain   | ... gr. ss.                | 1 drachm            | ... ℥ i, or ℥ j.     |
| 1 „                   | ... gr. j, or gr. i.       | $1\frac{1}{2}$ „    | ... ℥ iss.           |
| $1\frac{1}{2}$ „      | ... gr. iss.               | 2 „                 | ... ℥ ii, or ℥ ij.   |
| 2 „                   | ... gr. ii, or gr. ij.     | 3 „                 | ... ℥ iii, or ℥ iij. |
| $2\frac{1}{2}$ „      | ... gr. iiss.              | $3\frac{1}{2}$ „    | ... ℥ iiiss.         |
| 4 „                   | ... gr. iv.                | $\frac{1}{2}$ ounce | ... ℥ ss.            |
| 8 „                   | ... gr. viii. or gr. viij. | 1 „                 | ... ℥ i, or ℥ j.     |
| $\frac{1}{2}$ scruple | ... ℥ ss.                  | $1\frac{1}{2}$ „    | ... ℥ iss.           |
| 1 „                   | ... ℥ i. or ℥ j.           | $\frac{1}{2}$ pint  | ... Oss.             |
| $1\frac{1}{2}$ „      | ... ℥ iss.                 | 1 „                 | ... Oi or Oj.        |
| 2 „                   | ... ℥ ii, or ℥ ij.         | 1 gallon            | ... Ci or Cj         |



# Conversion of degrees Centigrade to degrees Fahrenheit and degrees Réaumur.

| Cent. | Fahr. | Réaumur. | Cent. | Fahr. | Réaumur. |
|-------|-------|----------|-------|-------|----------|
| -40   | -40   | -32      | +14   | +57.2 | +11.2    |
| 39    | 38.2  | 31.2     | 15    | 59    | 12       |
| 38    | 36.4  | 30.4     | 16    | 60.8  | 12.8     |
| 37    | 34.6  | 29.6     | 17    | 62.6  | 13.6     |
| 36    | 32.8  | 28.8     | 18    | 64.4  | 14.4     |
| 35    | 31    | 28       | 19    | 66.2  | 15.2     |
| 34    | 29.2  | 27.2     | 20    | 68    | 16       |
| 33    | 27.4  | 26.4     | 21    | 69.8  | 16.8     |
| 32    | 25.6  | 25.6     | 22    | 71.6  | 17.6     |
| 31    | 23.8  | 24.8     | 23    | 73.4  | 18.4     |
| 30    | 22    | 24       | 24    | 75.2  | 19.2     |
| 29    | 20.2  | 23.2     | 25    | 77    | 20       |
| 28    | 18.4  | 22.4     | 26    | 78.8  | 20.8     |
| 27    | 16.6  | 21.6     | 27    | 80.6  | 21.6     |
| 26    | 14.8  | 20.8     | 28    | 82.4  | 22.4     |
| 25    | 13    | 20       | 29    | 84.2  | 23.2     |
| 24    | 11.2  | 19.2     | 30    | 86    | 24       |
| 23    | 9.4   | 18.4     | 31    | 87.8  | 24.8     |
| 22    | 7.6   | 17.6     | 32    | 89.6  | 25.6     |
| 21    | 5.8   | 16.8     | 33    | 91.4  | 26.4     |
| 20    | 4     | 16       | 34    | 93.2  | 27.2     |
| 19    | 2.2   | 15.2     | 35    | 95    | 28       |
| 18    | 0.4   | 14.4     | 36    | 96.8  | 28.8     |
| 17    | +1.4  | 13.6     | 37    | 98.6  | 29.6     |
| 16    | 3.2   | 12.8     | 38    | 100.4 | 30.4     |
| 15    | 5     | 12       | 39    | 102.2 | 31.2     |
| 14    | 6.8   | 11.2     | 40    | 104   | 32       |
| 13    | 8.6   | 10.4     | 41    | 105.8 | 32.8     |
| 12    | 10.4  | 9.6      | 42    | 107.6 | 33.6     |
| 11    | 12.2  | 8.8      | 43    | 109.4 | 34.4     |
| 10    | 14    | 8        | 44    | 111.2 | 35.2     |
| 9     | 15.8  | 7.2      | 45    | 113   | 36       |
| 8     | 17.6  | 6.4      | 46    | 114.8 | 36.8     |
| 7     | 19.4  | 5.6      | 47    | 116.6 | 37.6     |
| 6     | 21.2  | 4.8      | 48    | 118.4 | 38.4     |
| 5     | 23    | 4        | 49    | 120.2 | 39.2     |
| 4     | 24.8  | 3.2      | 50    | 122   | 40       |
| 3     | 26.6  | 2.4      | 51    | 123.8 | 40.8     |
| 2     | 28.4  | 1.6      | 52    | 125.6 | 41.6     |
| 1     | 30.2  | 0.8      | 53    | 127.4 | 42.4     |
| 0     | 32    | 0        | 54    | 129.2 | 43.2     |
| +1    | 33.8  | +0.8     | 55    | 131   | 44       |
| 2     | 35.6  | 1.6      | 56    | 132.8 | 44.8     |
| 3     | 37.4  | 2.4      | 57    | 134.6 | 45.6     |
| 4     | 39.2  | 3.2      | 58    | 136.4 | 46.4     |
| 5     | 41    | 4        | 59    | 138.2 | 47.2     |
| 6     | 42.8  | 4.8      | 60    | 140   | 48       |
| 7     | 44.6  | 5.6      | 61    | 141.8 | 48.8     |
| 8     | 46.4  | 6.4      | 62    | 143.6 | 49.6     |
| 9     | 48.2  | 7.2      | 63    | 145.4 | 50.4     |
| 10    | 50    | 8        | 64    | 147.2 | 51.2     |
| 11    | 51.8  | 8.8      | 65    | 149   | 52       |
| 12    | 53.6  | 9.6      | 66    | 150.8 | 52.8     |
| 13    | 55.4  | 10.4     | 67    | 152.6 | 53.6     |

| Cent. | Fahr. | Réaumur. | Cent. | Fahr. | Réaumur. |
|-------|-------|----------|-------|-------|----------|
| 68    | 154.4 | 54.4     | 85    | 185   | 68       |
| 69    | 156.2 | 55.2     | 86    | 186.8 | 68.8     |
| 70    | 158   | 56       | 87    | 188.6 | 69.6     |
| 71    | 159.8 | 56.8     | 88    | 190.4 | 70.4     |
| 72    | 161.6 | 57.6     | 89    | 192.2 | 71.2     |
| 73    | 163.4 | 58.4     | 90    | 194   | 72       |
| 74    | 165.2 | 59.2     | 91    | 195.8 | 72.8     |
| 75    | 167   | 60       | 92    | 197.6 | 73.6     |
| 76    | 168.8 | 60.8     | 93    | 199.4 | 74.4     |
| 77    | 170.6 | 61.6     | 94    | 201.2 | 75.2     |
| 78    | 172.4 | 62.4     | 95    | 203   | 76       |
| 79    | 174.2 | 63.2     | 96    | 204.8 | 76.8     |
| 80    | 176   | 64       | 97    | 206.6 | 77.6     |
| 81    | 177.8 | 64.8     | 98    | 208.4 | 78.4     |
| 82    | 179.6 | 65.6     | 99    | 210.2 | 79.2     |
| 83    | 181.4 | 66.4     | 100   | 212   | 80       |
| 84    | 183.2 | 67.2     |       |       |          |

Conversion of degrees Fahrenheit to  
degrees Centigrade and degrees Réaumur.

| Fahr. | Cent. | Réaumur. | Fahr. | Cent. | Réaumur. |
|-------|-------|----------|-------|-------|----------|
| -40   | -40   | -32      | -13   | -25   | -20      |
| 39    | 39.44 | 31.56    | 12    | 24.44 | 19.56    |
| 38    | 38.89 | 31.11    | 11    | 23.89 | 19.11    |
| 37    | 38.33 | 30.67    | 10    | 23.33 | 18.67    |
| 36    | 37.78 | 30.22    | 9     | 22.78 | 18.22    |
| 35    | 37.22 | 29.78    | 8     | 22.22 | 17.78    |
| 34    | 36.67 | 29.33    | 7     | 21.67 | 17.33    |
| 33    | 36.11 | 28.89    | 6     | 21.11 | 16.89    |
| 32    | 35.55 | 28.44    | 5     | 20.55 | 16.44    |
| 31    | 35    | 28       | 4     | 20    | 16       |
| 30    | 34.44 | 27.56    | 3     | 19.44 | 15.56    |
| 29    | 33.89 | 27.11    | 2     | 18.89 | 15.11    |
| 28    | 33.33 | 26.67    | 1     | 18.33 | 14.67    |
| 27    | 32.78 | 26.22    | 0     | 17.78 | 14.22    |
| 26    | 32.22 | 25.78    | +1    | 17.22 | 13.78    |
| 25    | 31.67 | 25.33    | 2     | 16.67 | 13.33    |
| 24    | 31.11 | 24.89    | 3     | 16.11 | 12.89    |
| 23    | 30.56 | 24.44    | 4     | 15.55 | 12.44    |
| 22    | 30    | 24       | 5     | 15    | 12       |
| 21    | 29.44 | 23.56    | 6     | 14.44 | 11.56    |
| 20    | 28.89 | 23.11    | 7     | 13.89 | 11.11    |
| 19    | 28.33 | 22.67    | 8     | 13.33 | 10.67    |
| 18    | 27.78 | 22.22    | 9     | 12.78 | 10.22    |
| 17    | 27.22 | 21.78    | 10    | 12.22 | 9.78     |
| 16    | 26.67 | 21.33    | 11    | 11.67 | 9.33     |
| 15    | 26.11 | 20.89    | 12    | 11.11 | 8.89     |
| 14    | 25.55 | 20.44    | 13    | 10.55 | 8.44     |

| Fahr. | Cent. | Réaumur. | Fahr. | Cent.  | Réaumur. |
|-------|-------|----------|-------|--------|----------|
| +14   | -10   | -8       | +70   | +21.11 | +16.89   |
| 15    | 9.44  | 7.56     | 71    | 21.67  | 17.33    |
| 16    | 8.89  | 7.11     | 72    | 22.22  | 17.78    |
| 17    | 8.33  | 6.67     | 73    | 22.78  | 18.22    |
| 18    | 7.78  | 6.22     | 74    | 23.33  | 18.67    |
| 19    | 7.22  | 5.78     | 75    | 23.89  | 19.11    |
| 20    | 6.67  | 5.33     | 76    | 24.44  | 19.56    |
| 21    | 6.11  | 4.89     | 77    | 25     | 20       |
| 22    | 5.55  | 4.44     | 78    | 25.55  | 20.44    |
| 23    | 5     | 4        | 79    | 26.11  | 20.89    |
| 24    | 4.44  | 3.56     | 80    | 26.67  | 21.33    |
| 25    | 3.89  | 3.11     | 81    | 27.22  | 21.78    |
| 26    | 3.33  | 2.67     | 82    | 27.78  | 22.22    |
| 27    | 2.78  | 2.22     | 83    | 28.33  | 22.67    |
| 28    | 2.22  | 1.78     | 84    | 28.89  | 23.11    |
| 29    | 1.67  | 1.33     | 85    | 29.44  | 23.56    |
| 30    | 1.11  | 0.89     | 86    | 30     | 24       |
| 31    | 0.55  | 0.44     | 87    | 30.55  | 24.44    |
| 32    | 0     | 0        | 88    | 31.11  | 24.89    |
| 33    | +0.55 | +0.44    | 89    | 31.67  | 25.33    |
| 34    | 1.11  | 0.89     | 90    | 32.22  | 25.78    |
| 35    | 1.67  | 1.33     | 91    | 32.78  | 26.22    |
| 36    | 2.22  | 1.78     | 92    | 33.33  | 26.67    |
| 37    | 2.78  | 2.22     | 93    | 33.89  | 27.11    |
| 38    | 3.33  | 2.67     | 94    | 34.44  | 27.56    |
| 39    | 3.89  | 3.11     | 95    | 35     | 28       |
| 40    | 4.44  | 3.56     | 96    | 35.55  | 28.44    |
| 41    | 5     | 4        | 97    | 36.11  | 28.89    |
| 42    | 5.55  | 4.44     | 98    | 36.67  | 29.33    |
| 43    | 6.11  | 4.89     | 99    | 37.22  | 29.78    |
| 44    | 6.67  | 5.33     | 100   | 37.78  | 30.22    |
| 45    | 7.22  | 5.78     | 101   | 38.33  | 30.67    |
| 46    | 7.78  | 6.22     | 102   | 38.89  | 31.11    |
| 47    | 8.33  | 6.67     | 103   | 39.44  | 31.56    |
| 48    | 8.89  | 7.11     | 104   | 40     | 32       |
| 49    | 9.44  | 7.56     | 105   | 40.55  | 32.44    |
| 50    | 10    | 8        | 106   | 41.11  | 32.89    |
| 51    | 10.55 | 8.44     | 107   | 41.67  | 33.33    |
| 52    | 11.11 | 8.89     | 108   | 42.22  | 33.78    |
| 53    | 11.67 | 9.33     | 109   | 42.78  | 34.22    |
| 54    | 12.22 | 9.78     | 110   | 43.33  | 34.67    |
| 55    | 12.78 | 10.22    | 111   | 43.89  | 35.11    |
| 56    | 13.33 | 10.67    | 112   | 44.44  | 35.56    |
| 57    | 13.89 | 11.11    | 113   | 45     | 36       |
| 58    | 14.44 | 11.56    | 114   | 45.55  | 36.44    |
| 59    | 15    | 12       | 115   | 46.11  | 36.89    |
| 60    | 15.56 | 12.44    | 116   | 46.67  | 37.33    |
| 61    | 16.11 | 12.89    | 117   | 47.22  | 37.78    |
| 62    | 16.67 | 13.33    | 118   | 47.78  | 38.22    |
| 63    | 17.22 | 13.78    | 119   | 48.33  | 38.67    |
| 64    | 17.78 | 14.22    | 120   | 48.89  | 39.11    |
| 65    | 18.33 | 14.67    | 121   | 49.44  | 39.56    |
| 66    | 18.89 | 15.11    | 122   | 50     | 40       |
| 67    | 19.44 | 15.56    | 123   | 50.55  | 40.44    |
| 68    | 20    | 16       | 124   | 51.11  | 40.89    |
| 69    | 20.55 | 16.44    | 125   | 51.67  | 41.33    |

| Fahr. | Cent.  | Réaumur. | Fahr. | Cent.  | Réaumur. |
|-------|--------|----------|-------|--------|----------|
| +126  | +52.22 | +41.78   | +170  | +76.67 | +61.33   |
| 127   | 52.78  | 42.22    | 171   | 77.22  | 61.78    |
| 128   | 53.33  | 42.67    | 172   | 77.78  | 62.22    |
| 129   | 53.89  | 43.11    | 173   | 78.33  | 62.67    |
| 130   | 54.44  | 43.56    | 174   | 78.89  | 63.11    |
| 131   | 55     | 44       | 175   | 79.44  | 63.56    |
| 132   | 55.55  | 44.44    | 176   | 80     | 64       |
| 133   | 56.11  | 44.89    | 177   | 80.55  | 64.44    |
| 134   | 56.67  | 45.33    | 178   | 81.11  | 64.89    |
| 135   | 57.22  | 45.78    | 179   | 81.67  | 65.33    |
| 136   | 57.78  | 46.22    | 180   | 82.22  | 65.78    |
| 137   | 58.33  | 46.67    | 181   | 82.78  | 66.22    |
| 138   | 58.89  | 47.11    | 182   | 83.33  | 66.67    |
| 139   | 59.44  | 47.56    | 183   | 83.89  | 67.11    |
| 140   | 60     | 48       | 184   | 84.44  | 67.56    |
| 141   | 60.55  | 48.44    | 185   | 85     | 68       |
| 142   | 61.11  | 48.89    | 186   | 85.55  | 68.44    |
| 143   | 61.67  | 49.33    | 187   | 86.11  | 68.89    |
| 144   | 62.22  | 49.78    | 188   | 86.67  | 69.33    |
| 145   | 62.78  | 50.22    | 189   | 87.22  | 69.78    |
| 146   | 63.33  | 50.67    | 190   | 87.78  | 70.22    |
| 147   | 63.89  | 51.11    | 191   | 88.33  | 70.67    |
| 148   | 64.44  | 51.56    | 192   | 88.89  | 71.11    |
| 149   | 65     | 52       | 193   | 89.44  | 71.56    |
| 150   | 65.55  | 52.44    | 194   | 90     | 72       |
| 151   | 66.11  | 52.89    | 195   | 90.55  | 72.44    |
| 152   | 66.67  | 53.33    | 196   | 91.11  | 72.89    |
| 153   | 67.22  | 53.78    | 197   | 91.67  | 73.33    |
| 154   | 67.78  | 54.22    | 198   | 92.22  | 73.78    |
| 155   | 68.33  | 54.67    | 199   | 92.78  | 74.22    |
| 156   | 68.89  | 55.11    | 200   | 93.33  | 74.67    |
| 157   | 69.44  | 55.56    | 201   | 93.89  | 75.11    |
| 158   | 70     | 56       | 202   | 94.44  | 75.56    |
| 159   | 70.55  | 56.44    | 203   | 95     | 76       |
| 160   | 71.11  | 56.89    | 204   | 95.55  | 76.44    |
| 161   | 71.67  | 57.33    | 205   | 96.11  | 76.89    |
| 162   | 72.22  | 57.78    | 206   | 96.67  | 77.33    |
| 163   | 72.78  | 58.22    | 207   | 97.22  | 77.78    |
| 164   | 73.33  | 58.67    | 208   | 97.78  | 78.22    |
| 165   | 73.89  | 59.11    | 209   | 98.33  | 78.67    |
| 166   | 74.44  | 59.56    | 210   | 98.89  | 79.11    |
| 167   | 75     | 60       | 211   | 99.44  | 79.56    |
| 168   | 75.55  | 60.44    | 212   | 100    | 80       |
| 169   | 76.11  | 60.89    |       |        |          |

| Cent. | Fahr. | Cent. | Fahr. | Cent. | Fahr. |
|-------|-------|-------|-------|-------|-------|
| 105   | 221   | 140   | 284   | 175   | 347   |
| 110   | 230   | 145   | 293   | 180   | 356   |
| 115   | 239   | 150   | 302   | 185   | 365   |
| 120   | 248   | 155   | 311   | 190   | 374   |
| 125   | 257   | 160   | 320   | 200   | 392   |
| 130   | 266   | 165   | 329   | 250   | 482   |
| 135   | 275   | 170   | 338   | 300   | 572   |

## Barometer Readings.

CONVERSION OF INCHES INTO MILLIMETRES OF MERCURY.

| in.  | 0      | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      |
|------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 29.0 | 736.59 | 736.85 | 737.10 | 737.36 | 737.61 | 737.86 | 738.12 | 738.37 | 738.63 | 738.88 |
| 29.1 | 739.13 | 739.39 | 739.64 | 739.90 | 740.15 | 740.40 | 740.66 | 740.91 | 741.17 | 741.42 |
| 29.2 | 741.67 | 741.93 | 742.18 | 742.44 | 742.69 | 742.94 | 743.20 | 743.45 | 743.71 | 743.96 |
| 29.3 | 744.21 | 744.47 | 744.72 | 744.98 | 745.23 | 745.48 | 745.74 | 745.99 | 746.25 | 746.50 |
| 29.4 | 746.75 | 747.01 | 747.26 | 747.52 | 747.77 | 748.02 | 748.27 | 748.53 | 748.78 | 749.04 |
| 29.5 | 749.29 | 749.55 | 749.80 | 750.06 | 750.31 | 750.56 | 750.82 | 751.07 | 751.33 | 751.58 |
| 29.6 | 751.83 | 752.09 | 752.34 | 752.60 | 752.85 | 753.10 | 753.36 | 753.61 | 753.87 | 754.12 |
| 29.7 | 754.37 | 754.63 | 754.88 | 755.14 | 755.39 | 755.64 | 755.90 | 756.15 | 756.41 | 756.65 |
| 29.8 | 756.91 | 757.17 | 757.42 | 757.68 | 757.93 | 758.18 | 758.44 | 758.69 | 758.95 | 759.20 |
| 29.9 | 759.45 | 759.71 | 759.96 | 760.22 | 760.47 | 760.72 | 760.98 | 761.23 | 761.49 | 761.74 |
| 30.0 | 761.99 | 762.25 | 762.50 | 762.76 | 763.01 | 763.26 | 763.52 | 763.77 | 764.03 | 764.28 |
| 30.1 | 764.53 | 764.79 | 765.04 | 765.30 | 765.55 | 765.80 | 766.06 | 766.31 | 766.57 | 766.82 |
| 30.2 | 767.07 | 767.33 | 767.58 | 767.84 | 768.09 | 768.34 | 768.60 | 768.85 | 769.11 | 769.36 |
| 30.3 | 769.61 | 769.87 | 770.12 | 770.38 | 770.63 | 770.88 | 771.14 | 771.39 | 771.65 | 771.90 |
| 30.4 | 772.15 | 772.41 | 772.66 | 772.92 | 773.17 | 773.42 | 773.68 | 773.93 | 774.19 | 774.44 |
| 30.5 | 774.69 | 774.95 | 775.20 | 775.46 | 775.71 | 775.96 | 776.22 | 776.47 | 776.73 | 776.98 |
| 30.6 | 777.23 | 777.49 | 777.74 | 778.00 | 778.25 | 778.50 | 778.76 | 779.01 | 779.27 | 779.52 |
| 30.7 | 779.77 | 780.03 | 780.28 | 780.54 | 780.79 | 781.04 | 781.30 | 781.55 | 781.81 | 782.06 |
| 30.8 | 782.31 | 782.57 | 782.82 | 783.08 | 783.33 | 783.58 | 783.84 | 784.09 | 784.35 | 784.60 |
| 30.9 | 784.85 | 785.11 | 785.36 | 785.62 | 785.87 | 786.12 | 786.38 | 786.63 | 786.89 | 787.14 |
| 31.0 | 787.39 | 787.65 | 787.90 | 788.16 | 788.41 | 788.66 | 788.82 | 789.17 | 789.43 | 789.68 |

CONVERSION OF MILLIMETRES INTO INCHES OF MERCURY.

| mm. | 0     | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 700 | 27.56 | 27.60 | 27.64 | 27.68 | 27.72 | 27.76 | 27.80 | 27.84 | 27.88 | 27.91 |
| 710 | 27.95 | 27.99 | 28.03 | 28.07 | 28.11 | 28.15 | 28.19 | 28.23 | 28.27 | 28.31 |
| 720 | 28.35 | 28.39 | 28.43 | 28.47 | 28.50 | 28.54 | 28.58 | 28.62 | 28.66 | 28.70 |
| 730 | 28.74 | 28.78 | 28.82 | 28.86 | 28.90 | 28.94 | 28.98 | 29.02 | 29.06 | 29.10 |
| 740 | 29.13 | 29.17 | 29.21 | 29.25 | 29.29 | 29.33 | 29.37 | 29.41 | 29.45 | 29.49 |
| 750 | 29.53 | 29.57 | 29.61 | 29.65 | 29.69 | 29.73 | 29.77 | 29.80 | 29.84 | 29.88 |
| 760 | 29.92 | 29.96 | 30.00 | 30.04 | 30.08 | 30.12 | 30.16 | 30.20 | 30.24 | 30.28 |
| 770 | 30.32 | 30.36 | 30.39 | 30.43 | 30.47 | 30.51 | 30.55 | 30.59 | 30.63 | 30.67 |
| 780 | 30.71 | 30.75 | 30.79 | 30.83 | 30.87 | 30.91 | 30.95 | 30.99 | 31.02 | 31.06 |

## HYDROMETRIC TABLES.

The *Twaddell Hydrometer*, generally employed in England, has a scale of from  $0^{\circ}$  to  $200^{\circ}$ , corresponding to change in Specific Gravity from 1 to 2, the degrees representing constant increases. Water at  $4^{\circ}\text{C}$ . is considered to have a Specific Gravity of 1000 units, hence an increase in Specific Gravity of 5 units corresponds to an increase of  $1^{\circ}\text{Tw}$ .

*Conversion of degrees Twaddell to Specific Gravity:*

$$\text{Specific Gravity} = 1 + \frac{5(^{\circ}\text{Tw.})}{1000}$$

The original Baumé Hydrometer scale is graduated so that for liquids heavier than water,  $0^{\circ}$  is the point to which the hydrometer sinks in water, and  $10^{\circ}$  the point to which it sinks in a 10% solution of sodium chloride; for liquids lighter than water,  $0^{\circ}$  is the point to which the hydrometer sinks in the 10% solution of sodium chloride, and  $10^{\circ}$  the point to which it sinks in water, both liquids being at  $17.5^{\circ}\text{C}$ . The conversion may be calculated from the following formulæ:—

For liquids heavier than water,

$$\text{Specific Gravity} = \frac{146.78}{146.78 - ^{\circ}\text{Bé.}}$$

For liquids lighter than water,

$$\text{Specific Gravity} = \frac{146.78}{136.78 + ^{\circ}\text{Bé.}}$$

The *continental* Baumé Hydrometer has the “rational” scale proposed by Lunge, in which  $0^{\circ}$  is the point to which the hydrometer sinks in water, and  $66^{\circ}$  the point to which it sinks in sulphuric acid of Sp. gr. 1.842, both liquids being at  $15^{\circ}\text{C}$ .

*Baumé "rational" scale :*

Specific Gravity at 15°C. (compared to water at 15°C.=1)

$$= \frac{144.3}{144.3 - ^\circ\text{Bé.}}$$

The *American* Baumé Hydrometer scale, adopted by the Manufacturing Chemists' Association of the United States, is calculated from the following formulæ, according to the Bureau of Standards, Circulars 19 and 57 :—

For liquids heavier than water at 60°F. (=15.55°C.),

$$^\circ\text{Bé} = 145 - \frac{145}{\text{Sp. Gr.}} ; \text{Specific Gravity} = \frac{145}{145 - ^\circ\text{Bé.}}$$

For liquids lighter than water,

$$^\circ\text{Bé} = \frac{140}{\text{Sp. Gr.}} - 130 ; \text{Specific Gravity} = \frac{140}{130 + ^\circ\text{Bé.}}$$

### Conversion of "rational" degrees Baumé (heavier than water) to Specific Gravity.

| $^\circ\text{Bé.}$ | 0°    | 1°    | 2°    | 3°    | 4°    | 5°    | 6°    | 7°    | 8°    | 9°    |
|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| -                  | 1.000 | 1.007 | 1.014 | 1.021 | 1.029 | 1.036 | 1.043 | 1.051 | 1.059 | 1.066 |
| 10                 | 1.074 | 1.082 | 1.091 | 1.099 | 1.107 | 1.116 | 1.125 | 1.134 | 1.143 | 1.152 |
| 20                 | 1.161 | 1.170 | 1.180 | 1.190 | 1.200 | 1.210 | 1.220 | 1.230 | 1.241 | 1.251 |
| 30                 | 1.262 | 1.274 | 1.285 | 1.296 | 1.308 | 1.320 | 1.332 | 1.345 | 1.357 | 1.370 |
| 40                 | 1.384 | 1.397 | 1.411 | 1.424 | 1.439 | 1.453 | 1.468 | 1.483 | 1.498 | 1.514 |
| 50                 | 1.530 | 1.547 | 1.563 | 1.580 | 1.598 | 1.616 | 1.634 | 1.652 | 1.672 | 1.692 |
| 60                 | 1.712 | 1.732 | 1.753 | 1.775 | 1.797 | 1.820 | 1.843 | 1.867 | 1.891 | 1.916 |



### Conversion of American degrees Baumé (heavier than water) to Specific Gravity.

| °Bé | 0°    | 1°    | 2°    | 3°    | 4°    | 5°    | 6°    | 7°    | 8°    | 9°    |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| —   | 1.000 | 1.007 | 1.014 | 1.021 | 1.028 | 1.036 | 1.043 | 1.051 | 1.058 | 1.066 |
| 10  | 1.074 | 1.082 | 1.090 | 1.098 | 1.107 | 1.115 | 1.124 | 1.133 | 1.142 | 1.151 |
| 20  | 1.160 | 1.169 | 1.179 | 1.188 | 1.198 | 1.208 | 1.218 | 1.229 | 1.239 | 1.250 |
| 30  | 1.261 | 1.272 | 1.283 | 1.295 | 1.306 | 1.318 | 1.330 | 1.343 | 1.355 | 1.368 |
| 40  | 1.381 | 1.394 | 1.408 | 1.422 | 1.436 | 1.450 | 1.465 | 1.480 | 1.495 | 1.510 |
| 50  | 1.526 | 1.543 | 1.559 | 1.576 | 1.593 | 1.611 | 1.629 | 1.648 | 1.667 | 1.686 |
| 60  | 1.706 | 1.726 | 1.747 | 1.768 | 1.790 | 1.812 | 1.835 | 1.859 | 1.883 | 1.908 |

### Conversion of American degrees Baumé (lighter than water) to Specific Gravity.

| °Bé | 0°    | 1°    | 2°    | 3°    | 4°    | 5°    | 6°    | 7°    | 8°    | 9°    |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 10  | 1.000 | 0.993 | 0.986 | 0.979 | 0.972 | 0.966 | 0.959 | 0.952 | 0.946 | 0.940 |
| 20  | 0.933 | 0.927 | 0.921 | 0.915 | 0.909 | 0.903 | 0.897 | 0.892 | 0.886 | 0.880 |
| 30  | 0.875 | 0.870 | 0.864 | 0.859 | 0.854 | 0.848 | 0.843 | 0.838 | 0.833 | 0.828 |
| 40  | 0.824 | 0.819 | 0.814 | 0.809 | 0.804 | 0.800 | 0.795 | 0.791 | 0.786 | 0.782 |
| 50  | 0.778 | 0.773 | 0.769 | 0.765 | 0.761 | 0.757 | 0.753 | 0.749 | 0.745 | 0.741 |
| 60  | 0.737 | 0.733 | 0.729 | 0.725 | 0.722 | 0.718 | 0.714 | 0.711 | 0.707 | 0.704 |
| 70  | 0.700 | 0.696 | 0.693 | 0.690 | 0.686 | 0.683 | 0.680 | 0.676 | 0.673 | 0.670 |
| 80  | 0.667 | 0.664 | 0.660 | 0.657 | 0.654 | 0.651 | 0.648 | 0.645 | 0.642 | 0.639 |
| 90  | 0.636 | 0.633 | 0.631 | 0.628 | 0.625 | 0.622 | 0.619 | 0.617 | 0.614 | 0.611 |

## FIVE-FIGURE LOGARITHMS

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3  | 4  | 5  | 6  | 7  | 8  | 9  |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|----|----|----|----|----|----|----|
| 100 | 00300 | 043 | 087 | 130 | 173 | 217 | 260 | 303 | 346 | 389 | 4 | 8 | 13 | 17 | 21 | 26 | 30 | 35 | 39 |
| 101 | 432   | 475 | 518 | 561 | 604 | 647 | 689 | 732 | 775 | 817 | 4 | 8 | 13 | 17 | 21 | 26 | 30 | 34 | 39 |
| 102 | 860   | 903 | 945 | 988 | 030 | 072 | 115 | 157 | 199 | 242 | 4 | 8 | 13 | 17 | 21 | 25 | 30 | 34 | 38 |
| 103 | 01284 | 326 | 368 | 410 | 452 | 494 | 536 | 578 | 620 | 662 | 4 | 8 | 13 | 17 | 21 | 25 | 30 | 34 | 38 |
| 104 | 703   | 745 | 787 | 828 | 870 | 912 | 953 | 995 | 036 | 078 | 4 | 8 | 12 | 17 | 21 | 25 | 29 | 34 | 38 |
| 105 | 02119 | 160 | 202 | 243 | 284 | 325 | 366 | 407 | 449 | 490 | 4 | 8 | 12 | 17 | 21 | 25 | 29 | 33 | 37 |
| 106 | 531   | 572 | 612 | 653 | 694 | 735 | 776 | 816 | 857 | 898 | 4 | 8 | 12 | 16 | 20 | 24 | 29 | 33 | 37 |
| 107 | 938   | 979 | 019 | 060 | 100 | 141 | 181 | 222 | 262 | 302 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 |
| 108 | 03342 | 383 | 423 | 463 | 503 | 543 | 583 | 623 | 663 | 703 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 |
| 109 | 743   | 782 | 822 | 862 | 902 | 941 | 981 | 021 | 060 | 100 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 |
| 110 | 04139 | 179 | 218 | 258 | 297 | 336 | 376 | 415 | 454 | 493 | 4 | 8 | 12 | 16 | 20 | 24 | 27 | 31 | 35 |
| 111 | 532   | 571 | 610 | 650 | 689 | 727 | 766 | 805 | 844 | 883 | 4 | 8 | 12 | 16 | 20 | 23 | 27 | 31 | 35 |
| 112 | 922   | 961 | 999 | 038 | 077 | 115 | 154 | 192 | 231 | 269 | 4 | 8 | 12 | 16 | 20 | 23 | 27 | 31 | 35 |
| 113 | 05308 | 346 | 385 | 423 | 461 | 500 | 538 | 576 | 614 | 652 | 4 | 8 | 11 | 15 | 19 | 23 | 27 | 30 | 34 |
| 114 | 690   | 729 | 767 | 805 | 843 | 881 | 918 | 956 | 994 | 032 | 4 | 8 | 11 | 15 | 19 | 23 | 26 | 30 | 34 |
| 115 | 06070 | 108 | 145 | 183 | 221 | 258 | 296 | 333 | 371 | 408 | 4 | 8 | 11 | 15 | 19 | 23 | 26 | 30 | 34 |
| 116 | 446   | 483 | 521 | 558 | 595 | 633 | 670 | 707 | 744 | 781 | 4 | 7 | 11 | 15 | 19 | 22 | 26 | 30 | 33 |
| 117 | 819   | 856 | 893 | 930 | 967 | 004 | 041 | 078 | 115 | 151 | 4 | 7 | 11 | 15 | 19 | 22 | 25 | 29 | 33 |
| 118 | 07188 | 225 | 262 | 298 | 335 | 372 | 409 | 445 | 482 | 518 | 4 | 7 | 11 | 15 | 18 | 22 | 25 | 29 | 33 |
| 119 | 555   | 591 | 628 | 664 | 700 | 737 | 773 | 809 | 846 | 882 | 4 | 7 | 11 | 15 | 18 | 22 | 25 | 29 | 32 |
| 120 | 918   | 954 | 990 | 027 | 063 | 099 | 135 | 171 | 207 | 243 | 4 | 7 | 11 | 14 | 18 | 22 | 25 | 29 | 32 |
| 121 | 08279 | 314 | 350 | 386 | 422 | 458 | 493 | 529 | 565 | 600 | 4 | 7 | 11 | 14 | 18 | 21 | 25 | 29 | 32 |
| 122 | 636   | 672 | 707 | 743 | 778 | 814 | 849 | 884 | 920 | 955 | 4 | 7 | 11 | 14 | 18 | 21 | 25 | 28 | 32 |
| 123 | 991   | 025 | 061 | 096 | 132 | 167 | 202 | 237 | 272 | 307 | 4 | 7 | 11 | 14 | 18 | 21 | 25 | 28 | 32 |
| 124 | 09342 | 377 | 412 | 447 | 482 | 517 | 552 | 587 | 621 | 656 | 3 | 7 | 10 | 14 | 18 | 21 | 24 | 28 | 31 |
| 125 | 691   | 726 | 760 | 795 | 830 | 864 | 899 | 934 | 968 | 003 | 3 | 7 | 10 | 14 | 17 | 21 | 24 | 28 | 31 |
| 126 | 10037 | 072 | 106 | 140 | 175 | 209 | 243 | 278 | 312 | 346 | 3 | 7 | 10 | 14 | 17 | 21 | 24 | 27 | 31 |
| 127 | 380   | 415 | 449 | 483 | 517 | 551 | 585 | 619 | 653 | 687 | 3 | 7 | 10 | 14 | 17 | 20 | 24 | 27 | 31 |
| 128 | 721   | 755 | 789 | 823 | 856 | 890 | 924 | 958 | 992 | 025 | 3 | 7 | 10 | 14 | 17 | 20 | 24 | 27 | 30 |
| 129 | 11059 | 093 | 126 | 160 | 193 | 227 | 260 | 294 | 327 | 361 | 3 | 7 | 10 | 13 | 17 | 20 | 24 | 27 | 30 |
| 130 | 394   | 428 | 461 | 494 | 528 | 561 | 594 | 628 | 661 | 694 | 3 | 7 | 10 | 13 | 17 | 20 | 23 | 27 | 30 |
| 131 | 727   | 760 | 793 | 826 | 860 | 893 | 926 | 959 | 992 | 024 | 3 | 7 | 10 | 13 | 17 | 20 | 23 | 26 | 30 |
| 132 | 12057 | 090 | 123 | 156 | 189 | 222 | 254 | 287 | 320 | 352 | 3 | 7 | 10 | 13 | 16 | 20 | 23 | 26 | 29 |
| 133 | 385   | 418 | 450 | 483 | 516 | 548 | 581 | 613 | 646 | 678 | 3 | 6 | 10 | 13 | 16 | 20 | 23 | 26 | 29 |
| 134 | 710   | 743 | 775 | 808 | 840 | 872 | 905 | 937 | 969 | 001 | 3 | 6 | 10 | 13 | 16 | 19 | 23 | 26 | 29 |
| 135 | 13033 | 066 | 098 | 130 | 162 | 194 | 226 | 258 | 290 | 322 | 3 | 6 | 10 | 13 | 16 | 19 | 22 | 26 | 29 |
| 136 | 354   | 386 | 418 | 450 | 481 | 513 | 545 | 577 | 609 | 640 | 3 | 6 | 10 | 13 | 16 | 19 | 22 | 25 | 29 |
| 137 | 672   | 704 | 735 | 767 | 799 | 830 | 862 | 893 | 925 | 956 | 3 | 6 | 10 | 13 | 16 | 19 | 22 | 25 | 28 |
| 138 | 988   | 019 | 051 | 082 | 114 | 145 | 176 | 208 | 239 | 270 | 3 | 6 | 9  | 13 | 16 | 19 | 22 | 25 | 28 |
| 139 | 14301 | 333 | 364 | 395 | 426 | 457 | 489 | 520 | 551 | 582 | 3 | 6 | 9  | 12 | 16 | 19 | 22 | 25 | 28 |

# 140] Five-figure Logarithms—*continued.* [14

|     | 0     | 1   | 2          | 3          | 4          | 5          | 6          | 7          | 8          | 9          | 1 | 2 | 3 | 4  | 5  | 6  | 7  | 8  | 9  |
|-----|-------|-----|------------|------------|------------|------------|------------|------------|------------|------------|---|---|---|----|----|----|----|----|----|
| 140 | 14613 | 644 | 675        | 706        | 737        | 768        | 799        | 829        | 860        | 891        | 3 | 6 | 9 | 12 | 15 | 19 | 22 | 25 | 28 |
| 141 | 922   | 953 | 983        | <i>614</i> | <i>045</i> | <i>076</i> | <i>106</i> | <i>137</i> | <i>168</i> | <i>198</i> | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 25 | 28 |
| 142 | 15229 | 259 | 290        | 320        | 351        | 381        | 412        | 442        | 473        | 503        | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 |
| 143 | 534   | 564 | 594        | 625        | 655        | 685        | 715        | 746        | 776        | 806        | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 |
| 144 | 836   | 866 | 897        | 927        | 957        | 987        | <i>017</i> | <i>047</i> | <i>077</i> | <i>107</i> | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 |
| 145 | 16137 | 167 | 197        | 227        | 256        | 286        | 316        | 346        | 376        | 406        | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 |
| 146 | 435   | 465 | 495        | 524        | 554        | 584        | 613        | 643        | 673        | 702        | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 |
| 147 | 732   | 761 | 791        | 820        | 850        | 879        | 909        | 938        | 967        | 997        | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 26 |
| 148 | 17026 | 056 | 085        | 114        | 143        | 173        | 202        | 231        | 260        | 289        | 3 | 6 | 9 | 12 | 15 | 18 | 20 | 23 | 26 |
| 149 | 319   | 348 | 377        | 406        | 435        | 464        | 493        | 522        | 551        | 580        | 3 | 6 | 9 | 12 | 15 | 17 | 20 | 23 | 26 |
| 150 | 609   | 638 | 667        | 696        | 725        | 754        | 782        | 811        | 840        | 869        | 3 | 6 | 9 | 12 | 14 | 17 | 20 | 23 | 26 |
| 151 | 898   | 926 | 955        | 984        | <i>013</i> | <i>041</i> | <i>070</i> | <i>099</i> | <i>127</i> | <i>156</i> | 3 | 6 | 9 | 11 | 14 | 17 | 20 | 23 | 26 |
| 152 | 18184 | 213 | 241        | 270        | 298        | 327        | 355        | 384        | 412        | 441        | 3 | 6 | 9 | 11 | 14 | 17 | 20 | 23 | 25 |
| 153 | 469   | 498 | 526        | 554        | 583        | 611        | 639        | 667        | 696        | 724        | 3 | 6 | 9 | 11 | 14 | 17 | 20 | 23 | 25 |
| 154 | 752   | 780 | 808        | 837        | 865        | 893        | 921        | 949        | 977        | <i>005</i> | 3 | 6 | 8 | 11 | 14 | 17 | 20 | 23 | 25 |
| 155 | 19033 | 061 | 089        | 117        | 145        | 173        | 201        | 229        | 257        | 285        | 3 | 6 | 8 | 11 | 14 | 17 | 20 | 22 | 25 |
| 156 | 312   | 340 | 368        | 396        | 424        | 451        | 479        | 507        | 535        | 562        | 3 | 6 | 8 | 11 | 14 | 17 | 20 | 22 | 25 |
| 157 | 590   | 618 | 645        | 673        | 700        | 728        | 756        | 783        | 811        | 838        | 3 | 5 | 8 | 11 | 14 | 17 | 19 | 22 | 25 |
| 158 | 866   | 893 | 921        | 948        | 976        | <i>003</i> | <i>030</i> | <i>058</i> | <i>085</i> | <i>112</i> | 3 | 5 | 8 | 11 | 14 | 16 | 19 | 22 | 25 |
| 159 | 20140 | 167 | 194        | 222        | 249        | 276        | 303        | 330        | 358        | 385        | 3 | 5 | 8 | 11 | 14 | 16 | 19 | 22 | 25 |
| 160 | 412   | 439 | 466        | 493        | 520        | 547        | 575        | 602        | 629        | 656        | 3 | 5 | 8 | 11 | 14 | 16 | 19 | 22 | 24 |
| 161 | 683   | 710 | 736        | 763        | 790        | 817        | 844        | 871        | 898        | 925        | 3 | 5 | 8 | 11 | 13 | 16 | 19 | 22 | 24 |
| 162 | 951   | 978 | <i>005</i> | <i>032</i> | <i>059</i> | <i>085</i> | <i>112</i> | <i>139</i> | <i>165</i> | <i>192</i> | 3 | 5 | 8 | 11 | 13 | 16 | 19 | 21 | 24 |
| 163 | 21219 | 245 | 272        | 299        | 325        | 352        | 378        | 405        | 431        | 458        | 3 | 5 | 8 | 11 | 13 | 16 | 19 | 21 | 24 |
| 164 | 484   | 511 | 537        | 564        | 590        | 617        | 643        | 669        | 696        | 722        | 3 | 5 | 8 | 11 | 13 | 16 | 18 | 21 | 24 |
| 165 | 748   | 775 | 801        | 827        | 854        | 880        | 906        | 932        | 958        | 985        | 3 | 5 | 8 | 10 | 13 | 16 | 18 | 21 | 24 |
| 166 | 22011 | 037 | 063        | 089        | 115        | 141        | 167        | 194        | 220        | 246        | 3 | 5 | 8 | 10 | 13 | 16 | 18 | 21 | 23 |
| 167 | 272   | 298 | 324        | 350        | 376        | 401        | 427        | 453        | 479        | 505        | 3 | 5 | 8 | 10 | 13 | 16 | 18 | 21 | 23 |
| 168 | 531   | 557 | 583        | 608        | 634        | 660        | 686        | 712        | 737        | 763        | 3 | 5 | 8 | 10 | 13 | 15 | 18 | 21 | 23 |
| 169 | 789   | 814 | 840        | 866        | 891        | 917        | 943        | 968        | 994        | <i>019</i> | 3 | 5 | 8 | 10 | 13 | 15 | 18 | 21 | 23 |
| 170 | 23045 | 070 | 096        | 121        | 147        | 172        | 198        | 223        | 249        | 274        | 3 | 5 | 8 | 10 | 13 | 15 | 18 | 20 | 23 |
| 171 | 300   | 325 | 350        | 376        | 401        | 426        | 452        | 477        | 502        | 528        | 3 | 5 | 8 | 10 | 13 | 15 | 18 | 20 | 23 |
| 172 | 553   | 578 | 603        | 629        | 654        | 679        | 704        | 729        | 754        | 779        | 3 | 5 | 8 | 10 | 13 | 15 | 18 | 20 | 23 |
| 173 | 805   | 830 | 855        | 880        | 905        | 930        | 955        | 980        | <i>005</i> | <i>030</i> | 2 | 5 | 7 | 10 | 13 | 15 | 18 | 20 | 23 |
| 174 | 24055 | 080 | 105        | 130        | 155        | 180        | 204        | 229        | 254        | 279        | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 |
| 175 | 304   | 329 | 353        | 378        | 403        | 428        | 452        | 477        | 502        | 527        | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 |
| 176 | 551   | 576 | 601        | 625        | 650        | 674        | 699        | 724        | 748        | 773        | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 |
| 177 | 797   | 822 | 846        | 871        | 895        | 920        | 944        | 969        | 993        | <i>018</i> | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 |
| 178 | 25042 | 066 | 091        | 115        | 139        | 164        | 188        | 212        | 237        | 261        | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 19 | 22 |
| 179 | 285   | 310 | 334        | 358        | 382        | 406        | 431        | 455        | 479        | 503        | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 19 | 22 |

180] Five-figure Logarithms—*continued.* [25

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4  | 5  | 6  | 7  | 8  | 9  |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|----|----|----|----|----|----|
| 180 | 25527 | 551 | 575 | 600 | 624 | 648 | 672 | 696 | 720 | 744 | 2 | 5 | 7 | 10 | 12 | 14 | 17 | 19 | 22 |
| 181 | 768   | 792 | 816 | 840 | 864 | 888 | 912 | 935 | 959 | 983 | 3 | 5 | 7 | 10 | 12 | 14 | 17 | 19 | 22 |
| 182 | 26007 | 031 | 055 | 079 | 102 | 126 | 150 | 174 | 198 | 221 | 2 | 5 | 7 | 10 | 12 | 14 | 17 | 19 | 21 |
| 183 | 245   | 269 | 293 | 316 | 340 | 364 | 387 | 411 | 435 | 458 | 2 | 5 | 7 | 10 | 12 | 14 | 17 | 19 | 21 |
| 184 | 482   | 505 | 529 | 553 | 576 | 600 | 623 | 647 | 670 | 694 | 2 | 5 | 7 | 9  | 12 | 14 | 17 | 19 | 21 |
| 185 | 717   | 741 | 764 | 788 | 811 | 834 | 858 | 881 | 905 | 928 | 2 | 5 | 7 | 9  | 12 | 14 | 16 | 19 | 21 |
| 186 | 951   | 975 | 998 | 021 | 045 | 068 | 091 | 114 | 138 | 161 | 2 | 5 | 7 | 9  | 12 | 14 | 16 | 19 | 21 |
| 187 | 27184 | 207 | 231 | 254 | 277 | 300 | 323 | 346 | 370 | 393 | 2 | 5 | 7 | 9  | 12 | 14 | 16 | 19 | 21 |
| 188 | 416   | 439 | 462 | 485 | 508 | 531 | 554 | 577 | 600 | 623 | 2 | 5 | 7 | 9  | 12 | 14 | 16 | 18 | 21 |
| 189 | 646   | 669 | 692 | 715 | 738 | 761 | 784 | 807 | 829 | 852 | 2 | 5 | 7 | 9  | 11 | 14 | 16 | 18 | 21 |
| 190 | 875   | 898 | 921 | 944 | 967 | 989 | 012 | 035 | 058 | 081 | 2 | 5 | 7 | 9  | 11 | 14 | 16 | 18 | 21 |
| 191 | 28103 | 126 | 149 | 171 | 194 | 217 | 240 | 262 | 285 | 307 | 2 | 5 | 7 | 9  | 11 | 14 | 16 | 18 | 20 |
| 192 | 330   | 353 | 375 | 398 | 420 | 443 | 466 | 488 | 510 | 533 | 2 | 5 | 7 | 9  | 11 | 14 | 16 | 18 | 20 |
| 193 | 556   | 578 | 601 | 623 | 646 | 668 | 691 | 713 | 735 | 758 | 2 | 4 | 7 | 9  | 11 | 13 | 16 | 18 | 20 |
| 194 | 780   | 803 | 825 | 847 | 870 | 892 | 914 | 937 | 959 | 981 | 2 | 4 | 7 | 9  | 11 | 13 | 16 | 18 | 20 |
| 195 | 29003 | 026 | 048 | 070 | 092 | 115 | 137 | 159 | 181 | 203 | 2 | 4 | 7 | 9  | 11 | 13 | 16 | 18 | 20 |
| 196 | 226   | 248 | 270 | 292 | 314 | 336 | 358 | 380 | 403 | 425 | 2 | 4 | 7 | 9  | 11 | 13 | 15 | 18 | 20 |
| 197 | 447   | 469 | 491 | 513 | 535 | 557 | 579 | 601 | 623 | 645 | 2 | 4 | 7 | 9  | 11 | 13 | 15 | 18 | 20 |
| 198 | 667   | 688 | 710 | 732 | 754 | 776 | 798 | 820 | 842 | 863 | 2 | 4 | 7 | 9  | 11 | 13 | 15 | 18 | 20 |
| 199 | 885   | 907 | 929 | 951 | 973 | 994 | 016 | 038 | 060 | 081 | 2 | 4 | 7 | 9  | 11 | 13 | 15 | 17 | 20 |
| 200 | 30103 | 125 | 146 | 168 | 190 | 211 | 233 | 255 | 276 | 298 | 2 | 4 | 7 | 9  | 11 | 13 | 15 | 17 | 20 |
| 201 | 320   | 341 | 363 | 384 | 406 | 428 | 449 | 471 | 492 | 514 | 2 | 4 | 6 | 9  | 11 | 13 | 15 | 17 | 19 |
| 202 | 535   | 557 | 578 | 600 | 621 | 642 | 664 | 685 | 707 | 728 | 2 | 4 | 6 | 9  | 11 | 13 | 15 | 17 | 19 |
| 203 | 750   | 771 | 792 | 814 | 835 | 856 | 877 | 899 | 920 | 942 | 2 | 4 | 6 | 9  | 11 | 13 | 15 | 17 | 19 |
| 204 | 963   | 984 | 006 | 027 | 048 | 069 | 091 | 112 | 133 | 154 | 2 | 4 | 6 | 8  | 11 | 13 | 15 | 17 | 19 |
| 205 | 31175 | 197 | 218 | 239 | 260 | 281 | 302 | 323 | 345 | 366 | 2 | 4 | 6 | 8  | 11 | 13 | 15 | 17 | 19 |
| 206 | 387   | 408 | 429 | 450 | 471 | 492 | 513 | 534 | 555 | 576 | 2 | 4 | 6 | 8  | 11 | 13 | 15 | 17 | 19 |
| 207 | 597   | 618 | 639 | 660 | 681 | 702 | 723 | 744 | 765 | 785 | 2 | 4 | 6 | 8  | 10 | 13 | 15 | 17 | 19 |
| 208 | 806   | 827 | 848 | 869 | 890 | 911 | 931 | 952 | 973 | 994 | 2 | 4 | 6 | 8  | 10 | 13 | 15 | 17 | 19 |
| 209 | 32015 | 035 | 056 | 077 | 098 | 118 | 139 | 160 | 181 | 201 | 2 | 4 | 6 | 8  | 10 | 12 | 15 | 17 | 19 |
| 210 | 222   | 243 | 263 | 284 | 305 | 325 | 346 | 366 | 387 | 408 | 2 | 4 | 6 | 8  | 10 | 12 | 14 | 16 | 18 |
| 211 | 428   | 449 | 469 | 490 | 510 | 531 | 552 | 572 | 593 | 613 | 2 | 4 | 6 | 8  | 10 | 12 | 14 | 16 | 18 |
| 212 | 634   | 654 | 675 | 695 | 715 | 736 | 756 | 777 | 797 | 818 | 2 | 4 | 6 | 8  | 10 | 12 | 14 | 16 | 18 |
| 213 | 838   | 858 | 879 | 899 | 919 | 940 | 960 | 980 | 001 | 021 | 2 | 4 | 6 | 8  | 10 | 12 | 14 | 16 | 18 |
| 214 | 33041 | 062 | 082 | 102 | 122 | 143 | 163 | 183 | 203 | 224 | 2 | 4 | 6 | 8  | 10 | 12 | 14 | 16 | 18 |
| 215 | 244   | 264 | 284 | 304 | 325 | 345 | 365 | 385 | 405 | 425 | 2 | 4 | 6 | 8  | 10 | 12 | 14 | 16 | 18 |
| 216 | 445   | 465 | 486 | 506 | 526 | 546 | 566 | 586 | 606 | 626 | 2 | 4 | 6 | 8  | 10 | 12 | 14 | 16 | 18 |
| 217 | 646   | 666 | 686 | 706 | 726 | 746 | 766 | 786 | 806 | 826 | 2 | 4 | 6 | 8  | 10 | 12 | 14 | 16 | 18 |
| 218 | 846   | 866 | 885 | 905 | 925 | 945 | 965 | 985 | 005 | 025 | 2 | 4 | 6 | 8  | 10 | 12 | 14 | 16 | 18 |
| 219 | 34044 | 064 | 084 | 104 | 124 | 143 | 163 | 183 | 203 | 223 | 2 | 4 | 6 | 8  | 10 | 12 | 14 | 16 | 18 |

220] Five-figure Logarithms--*continued.*

[34

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5  | 6  | 7  | 8  | 9  |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|----|----|----|----|----|
| 220 | 34242 | 262 | 282 | 301 | 321 | 341 | 361 | 381 | 400 | 420 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 221 | 439   | 459 | 479 | 498 | 518 | 537 | 557 | 577 | 596 | 616 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 222 | 635   | 655 | 674 | 694 | 713 | 733 | 753 | 772 | 792 | 811 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 223 | 830   | 850 | 869 | 889 | 908 | 928 | 947 | 966 | 986 | 005 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 224 | 35025 | 044 | 064 | 083 | 102 | 122 | 141 | 160 | 180 | 199 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 15 | 17 |
| 225 | 218   | 238 | 257 | 276 | 295 | 315 | 334 | 353 | 372 | 392 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 15 | 17 |
| 226 | 411   | 430 | 449 | 468 | 488 | 507 | 526 | 545 | 564 | 583 | 2 | 4 | 6 | 8 | 10 | 12 | 13 | 15 | 17 |
| 227 | 603   | 622 | 641 | 660 | 679 | 698 | 717 | 736 | 755 | 774 | 2 | 4 | 6 | 8 | 10 | 11 | 13 | 15 | 17 |
| 228 | 793   | 813 | 832 | 851 | 870 | 889 | 908 | 927 | 946 | 965 | 2 | 4 | 6 | 8 | 10 | 11 | 13 | 15 | 17 |
| 229 | 984   | 003 | 021 | 040 | 059 | 078 | 097 | 116 | 135 | 154 | 2 | 4 | 6 | 8 | 9  | 11 | 13 | 15 | 17 |
| 230 | 36173 | 192 | 211 | 229 | 248 | 267 | 286 | 305 | 324 | 342 | 2 | 4 | 6 | 8 | 9  | 11 | 13 | 15 | 17 |
| 231 | 361   | 380 | 399 | 418 | 437 | 455 | 474 | 493 | 511 | 530 | 2 | 4 | 6 | 8 | 9  | 11 | 13 | 15 | 17 |
| 232 | 549   | 568 | 586 | 605 | 624 | 642 | 661 | 680 | 698 | 717 | 2 | 4 | 6 | 7 | 9  | 11 | 13 | 15 | 17 |
| 233 | 736   | 754 | 773 | 791 | 810 | 829 | 847 | 866 | 884 | 903 | 2 | 4 | 6 | 7 | 9  | 11 | 13 | 15 | 17 |
| 234 | 922   | 940 | 959 | 977 | 996 | 014 | 033 | 051 | 070 | 088 | 2 | 4 | 6 | 7 | 9  | 11 | 13 | 15 | 17 |
| 235 | 37107 | 125 | 144 | 162 | 181 | 200 | 218 | 236 | 254 | 273 | 2 | 4 | 6 | 7 | 9  | 11 | 13 | 15 | 17 |
| 236 | 291   | 310 | 328 | 346 | 365 | 383 | 401 | 420 | 438 | 457 | 2 | 4 | 6 | 7 | 9  | 11 | 13 | 15 | 17 |
| 237 | 475   | 493 | 511 | 530 | 548 | 566 | 585 | 603 | 621 | 639 | 2 | 4 | 5 | 7 | 9  | 11 | 13 | 15 | 16 |
| 238 | 658   | 676 | 694 | 712 | 731 | 749 | 767 | 785 | 803 | 822 | 2 | 4 | 5 | 7 | 9  | 11 | 13 | 15 | 16 |
| 239 | 840   | 858 | 876 | 894 | 912 | 931 | 949 | 967 | 985 | 003 | 2 | 4 | 5 | 7 | 9  | 11 | 13 | 14 | 16 |
| 240 | 38021 | 039 | 057 | 075 | 093 | 112 | 130 | 148 | 166 | 184 | 2 | 4 | 5 | 7 | 9  | 11 | 13 | 14 | 16 |
| 241 | 202   | 220 | 238 | 256 | 274 | 292 | 310 | 328 | 346 | 364 | 2 | 4 | 5 | 7 | 9  | 11 | 13 | 14 | 16 |
| 242 | 382   | 399 | 417 | 435 | 453 | 471 | 489 | 507 | 525 | 543 | 2 | 4 | 5 | 7 | 9  | 11 | 13 | 14 | 16 |
| 243 | 561   | 578 | 596 | 614 | 632 | 650 | 668 | 686 | 703 | 721 | 2 | 4 | 5 | 7 | 9  | 11 | 12 | 14 | 16 |
| 244 | 739   | 757 | 775 | 792 | 810 | 828 | 846 | 863 | 881 | 899 | 2 | 4 | 5 | 7 | 9  | 11 | 12 | 14 | 16 |
| 245 | 917   | 934 | 952 | 970 | 987 | 005 | 023 | 041 | 058 | 076 | 2 | 4 | 5 | 7 | 9  | 11 | 12 | 14 | 16 |
| 246 | 39094 | 111 | 129 | 146 | 164 | 182 | 199 | 217 | 235 | 252 | 2 | 4 | 5 | 7 | 9  | 11 | 12 | 14 | 16 |
| 247 | 270   | 287 | 305 | 322 | 340 | 358 | 375 | 393 | 410 | 428 | 2 | 4 | 5 | 7 | 9  | 11 | 12 | 14 | 16 |
| 248 | 445   | 463 | 480 | 498 | 515 | 533 | 550 | 568 | 585 | 602 | 2 | 3 | 5 | 7 | 9  | 10 | 12 | 14 | 16 |
| 249 | 620   | 637 | 655 | 672 | 690 | 707 | 724 | 742 | 759 | 777 | 2 | 3 | 5 | 7 | 9  | 10 | 12 | 14 | 16 |
| 250 | 794   | 811 | 829 | 846 | 863 | 881 | 898 | 915 | 933 | 950 | 2 | 3 | 5 | 7 | 9  | 10 | 12 | 14 | 16 |
| 251 | 967   | 985 | 002 | 019 | 037 | 054 | 071 | 088 | 106 | 123 | 2 | 3 | 5 | 7 | 9  | 10 | 12 | 14 | 16 |
| 252 | 40140 | 157 | 174 | 192 | 209 | 226 | 243 | 261 | 278 | 295 | 2 | 3 | 5 | 7 | 9  | 10 | 12 | 14 | 15 |
| 253 | 312   | 329 | 346 | 364 | 381 | 398 | 415 | 432 | 449 | 466 | 2 | 3 | 5 | 7 | 9  | 10 | 12 | 14 | 15 |
| 254 | 483   | 500 | 518 | 535 | 552 | 569 | 586 | 603 | 620 | 637 | 2 | 3 | 5 | 7 | 9  | 10 | 12 | 14 | 15 |
| 255 | 654   | 671 | 688 | 705 | 722 | 739 | 756 | 773 | 790 | 807 | 2 | 3 | 5 | 7 | 8  | 10 | 12 | 14 | 15 |
| 256 | 824   | 841 | 858 | 875 | 892 | 909 | 926 | 943 | 959 | 976 | 2 | 3 | 5 | 7 | 8  | 10 | 12 | 14 | 15 |
| 257 | 993   | 010 | 027 | 044 | 061 | 078 | 095 | 111 | 128 | 145 | 2 | 3 | 5 | 7 | 8  | 10 | 12 | 13 | 15 |
| 258 | 41162 | 179 | 196 | 212 | 229 | 246 | 263 | 280 | 296 | 313 | 2 | 3 | 5 | 7 | 8  | 10 | 12 | 13 | 15 |
| 259 | 330   | 347 | 363 | 380 | 397 | 414 | 430 | 447 | 464 | 481 | 2 | 3 | 5 | 7 | 8  | 10 | 12 | 13 | 15 |

260] Five-figure Logarithms—*continued.* [41

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6  | 7  | 8  | 9  |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|----|----|----|----|
| 260 | 41497 | 514 | 531 | 547 | 564 | 581 | 597 | 614 | 631 | 647 | 2 | 3 | 5 | 7 | 8 | 10 | 12 | 13 | 15 |
| 261 | 664   | 680 | 697 | 714 | 731 | 747 | 764 | 781 | 797 | 814 | 2 | 3 | 5 | 7 | 8 | 10 | 12 | 13 | 15 |
| 262 | 830   | 847 | 863 | 880 | 896 | 913 | 929 | 946 | 963 | 979 | 2 | 3 | 5 | 7 | 8 | 10 | 12 | 13 | 15 |
| 263 | 996   | 012 | 029 | 045 | 062 | 078 | 095 | 111 | 127 | 143 | 2 | 3 | 5 | 7 | 8 | 10 | 12 | 13 | 15 |
| 264 | 42160 | 177 | 193 | 209 | 226 | 243 | 259 | 275 | 292 | 308 | 2 | 3 | 5 | 7 | 8 | 10 | 11 | 13 | 15 |
| 265 | 325   | 341 | 357 | 374 | 390 | 406 | 423 | 439 | 455 | 472 | 2 | 3 | 5 | 7 | 8 | 10 | 11 | 13 | 15 |
| 266 | 488   | 504 | 521 | 537 | 553 | 570 | 586 | 602 | 619 | 635 | 2 | 3 | 5 | 7 | 8 | 10 | 11 | 13 | 15 |
| 267 | 651   | 667 | 684 | 700 | 716 | 732 | 749 | 765 | 781 | 797 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 15 |
| 268 | 813   | 830 | 846 | 862 | 878 | 894 | 910 | 927 | 943 | 959 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 15 |
| 269 | 975   | 991 | 008 | 024 | 040 | 056 | 072 | 088 | 104 | 120 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 14 |
| 270 | 43136 | 152 | 169 | 185 | 201 | 217 | 233 | 249 | 265 | 281 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 14 |
| 271 | 297   | 313 | 329 | 345 | 361 | 377 | 393 | 409 | 425 | 441 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 14 |
| 272 | 457   | 473 | 489 | 505 | 521 | 537 | 553 | 569 | 585 | 600 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 14 |
| 273 | 616   | 632 | 648 | 664 | 680 | 696 | 712 | 727 | 743 | 759 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 14 |
| 274 | 775   | 791 | 807 | 823 | 838 | 854 | 870 | 886 | 902 | 917 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 14 |
| 275 | 933   | 949 | 965 | 981 | 996 | 012 | 028 | 044 | 059 | 075 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 13 | 14 |
| 276 | 44091 | 107 | 122 | 138 | 154 | 170 | 185 | 201 | 217 | 232 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 13 | 14 |
| 277 | 248   | 264 | 279 | 295 | 311 | 326 | 342 | 358 | 373 | 389 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 13 | 14 |
| 278 | 404   | 420 | 436 | 451 | 467 | 483 | 498 | 514 | 529 | 545 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 12 | 14 |
| 279 | 560   | 576 | 592 | 607 | 623 | 638 | 654 | 669 | 685 | 700 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 12 | 14 |
| 280 | 716   | 731 | 747 | 762 | 778 | 793 | 809 | 824 | 840 | 855 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 12 | 14 |
| 281 | 871   | 886 | 902 | 917 | 932 | 948 | 963 | 979 | 994 | 010 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 12 | 14 |
| 282 | 45025 | 040 | 056 | 071 | 086 | 102 | 117 | 133 | 148 | 163 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 12 | 14 |
| 283 | 179   | 194 | 209 | 225 | 240 | 255 | 271 | 286 | 301 | 317 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 12 | 14 |
| 284 | 332   | 347 | 362 | 378 | 393 | 408 | 423 | 439 | 454 | 469 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 12 | 14 |
| 285 | 484   | 500 | 515 | 530 | 545 | 560 | 576 | 591 | 606 | 621 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 12 | 14 |
| 286 | 637   | 652 | 667 | 682 | 697 | 712 | 728 | 743 | 758 | 773 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 12 | 14 |
| 287 | 788   | 803 | 818 | 834 | 849 | 864 | 879 | 894 | 909 | 924 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 12 | 14 |
| 288 | 939   | 954 | 969 | 984 | 000 | 015 | 030 | 045 | 060 | 075 | 2 | 3 | 5 | 6 | 8 | 9  | 11 | 12 | 14 |
| 289 | 46090 | 105 | 120 | 135 | 150 | 165 | 180 | 195 | 210 | 225 | 1 | 3 | 4 | 6 | 8 | 9  | 10 | 12 | 13 |
| 290 | 240   | 255 | 270 | 285 | 300 | 315 | 330 | 344 | 359 | 374 | 1 | 3 | 4 | 6 | 7 | 9  | 10 | 12 | 13 |
| 291 | 389   | 404 | 419 | 434 | 449 | 464 | 479 | 494 | 509 | 523 | 1 | 3 | 4 | 6 | 7 | 9  | 10 | 12 | 13 |
| 292 | 538   | 553 | 568 | 583 | 598 | 613 | 627 | 642 | 657 | 672 | 1 | 3 | 4 | 6 | 7 | 9  | 10 | 12 | 13 |
| 293 | 687   | 702 | 716 | 731 | 746 | 761 | 776 | 790 | 805 | 820 | 1 | 3 | 4 | 6 | 7 | 9  | 10 | 12 | 13 |
| 294 | 835   | 849 | 864 | 879 | 894 | 909 | 923 | 938 | 953 | 967 | 1 | 3 | 4 | 6 | 7 | 9  | 10 | 12 | 13 |
| 295 | 982   | 997 | 012 | 026 | 041 | 056 | 070 | 085 | 100 | 114 | 1 | 3 | 4 | 6 | 7 | 9  | 10 | 12 | 13 |
| 296 | 47129 | 144 | 159 | 173 | 188 | 202 | 217 | 232 | 246 | 261 | 1 | 3 | 4 | 6 | 7 | 9  | 10 | 12 | 13 |
| 297 | 216   | 290 | 305 | 319 | 334 | 349 | 363 | 378 | 392 | 407 | 1 | 3 | 4 | 6 | 7 | 9  | 10 | 12 | 13 |
| 298 | 422   | 436 | 451 | 466 | 480 | 494 | 509 | 524 | 538 | 553 | 1 | 3 | 4 | 6 | 7 | 9  | 10 | 12 | 13 |
| 299 | 567   | 582 | 596 | 611 | 625 | 640 | 654 | 669 | 683 | 698 | 1 | 3 | 4 | 6 | 7 | 9  | 10 | 12 | 13 |



300] Five-figure Logarithms—*continued.*

[47

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7  | 8  | 9  |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|----|----|----|
| 300 | 47712 | 727 | 741 | 756 | 770 | 784 | 799 | 813 | 828 | 842 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 13 |
| 301 | 857   | 871 | 885 | 900 | 914 | 929 | 943 | 958 | 972 | 986 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 13 |
| 302 | 48001 | 015 | 029 | 044 | 058 | 073 | 087 | 101 | 116 | 130 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 11 | 13 |
| 303 | 144   | 159 | 173 | 187 | 202 | 216 | 230 | 244 | 258 | 273 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 11 | 13 |
| 304 | 2.7   | 302 | 316 | 330 | 344 | 359 | 373 | 387 | 401 | 416 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 11 | 13 |
| 305 | 430   | 444 | 458 | 473 | 487 | 501 | 515 | 530 | 544 | 558 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 11 | 13 |
| 306 | 572   | 586 | 601 | 615 | 629 | 643 | 657 | 671 | 686 | 700 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 11 | 13 |
| 307 | 714   | 728 | 742 | 756 | 770 | 785 | 799 | 813 | 827 | 841 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 |
| 308 | 855   | 869 | 883 | 887 | 911 | 926 | 940 | 954 | 968 | 982 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 |
| 309 | 996   | 010 | 024 | 038 | 052 | 066 | 080 | 094 | 108 | 122 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 |
| 310 | 49136 | 150 | 164 | 178 | 192 | 206 | 220 | 234 | 248 | 262 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 |
| 311 | 276   | 290 | 304 | 318 | 332 | 346 | 360 | 374 | 388 | 402 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 |
| 312 | 415   | 429 | 443 | 457 | 471 | 485 | 499 | 513 | 527 | 541 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 |
| 313 | 554   | 568 | 582 | 596 | 610 | 624 | 638 | 651 | 665 | 679 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 12 |
| 314 | 693   | 707 | 721 | 734 | 748 | 762 | 776 | 790 | 803 | 817 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 12 |
| 315 | 831   | 845 | 859 | 872 | 886 | 900 | 914 | 927 | 941 | 955 | 1 | 3 | 4 | 5 | 7 | 8 | 10 | 11 | 12 |
| 316 | 969   | 983 | 996 | 010 | 024 | 037 | 051 | 065 | 079 | 092 | 1 | 3 | 4 | 5 | 7 | 8 | 10 | 11 | 12 |
| 317 | 50106 | 119 | 133 | 147 | 161 | 174 | 188 | 202 | 215 | 229 | 1 | 3 | 4 | 5 | 7 | 8 | 10 | 11 | 12 |
| 318 | 243   | 256 | 270 | 284 | 297 | 311 | 325 | 338 | 352 | 365 | 1 | 3 | 4 | 5 | 7 | 8 | 10 | 11 | 12 |
| 319 | 379   | 393 | 407 | 420 | 433 | 447 | 461 | 474 | 488 | 501 | 1 | 3 | 4 | 5 | 7 | 8 | 10 | 11 | 12 |
| 320 | 515   | 529 | 542 | 556 | 569 | 583 | 596 | 610 | 624 | 637 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 11 | 12 |
| 321 | 650   | 664 | 678 | 691 | 705 | 718 | 732 | 745 | 759 | 772 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 11 | 12 |
| 322 | 786   | 799 | 813 | 826 | 839 | 853 | 866 | 880 | 893 | 907 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 11 | 12 |
| 323 | 920   | 934 | 947 | 961 | 974 | 987 | 001 | 014 | 028 | 041 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 11 | 12 |
| 324 | 51054 | 068 | 081 | 095 | 108 | 121 | 135 | 148 | 161 | 175 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 11 | 12 |
| 325 | 183   | 202 | 215 | 228 | 242 | 255 | 268 | 282 | 295 | 308 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 11 | 12 |
| 326 | 322   | 335 | 348 | 362 | 375 | 388 | 402 | 415 | 428 | 442 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 11 | 12 |
| 327 | 455   | 468 | 481 | 495 | 508 | 521 | 534 | 548 | 561 | 574 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 11 | 12 |
| 328 | 587   | 601 | 614 | 627 | 640 | 654 | 667 | 680 | 693 | 706 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 11 | 12 |
| 329 | 720   | 733 | 746 | 759 | 772 | 786 | 799 | 812 | 825 | 838 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 11 | 12 |
| 330 | 851   | 865 | 878 | 891 | 904 | 917 | 930 | 943 | 957 | 970 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 11 | 12 |
| 331 | 983   | 996 | 009 | 022 | 035 | 048 | 061 | 075 | 088 | 101 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 10 | 12 |
| 332 | 52114 | 127 | 140 | 153 | 166 | 179 | 192 | 205 | 218 | 231 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 10 | 12 |
| 333 | 244   | 257 | 270 | 284 | 297 | 310 | 323 | 336 | 349 | 362 | 1 | 3 | 4 | 5 | 7 | 8 | 9  | 10 | 12 |
| 334 | 375   | 388 | 401 | 414 | 427 | 440 | 453 | 466 | 479 | 492 | 1 | 3 | 4 | 5 | 6 | 8 | 9  | 10 | 12 |
| 335 | 504   | 517 | 530 | 543 | 556 | 569 | 582 | 595 | 608 | 621 | 1 | 3 | 4 | 5 | 6 | 8 | 9  | 10 | 12 |
| 336 | 634   | 647 | 660 | 673 | 686 | 699 | 711 | 724 | 737 | 750 | 1 | 3 | 4 | 5 | 6 | 8 | 9  | 10 | 12 |
| 337 | 763   | 776 | 789 | 802 | 815 | 827 | 840 | 853 | 866 | 879 | 1 | 3 | 4 | 5 | 6 | 8 | 9  | 10 | 12 |
| 338 | 892   | 905 | 917 | 930 | 943 | 956 | 969 | 982 | 994 | 007 | 1 | 3 | 4 | 5 | 6 | 8 | 9  | 10 | 12 |
| 339 | 53020 | 033 | 046 | 058 | 071 | 084 | 097 | 110 | 122 | 135 | 1 | 3 | 4 | 5 | 6 | 8 | 9  | 10 | 12 |



340] Five-figure Logarithms—*continued.* [53

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8  | 9  |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|----|----|
| 340 | 53148 | 161 | 173 | 186 | 199 | 212 | 224 | 237 | 250 | 263 | 1 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 |
| 341 | 275   | 288 | 301 | 314 | 326 | 339 | 352 | 364 | 377 | 390 | 1 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 |
| 342 | 403   | 415 | 428 | 441 | 453 | 466 | 479 | 491 | 504 | 517 | 1 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 |
| 343 | 529   | 542 | 555 | 567 | 580 | 593 | 605 | 618 | 631 | 643 | 1 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 |
| 344 | 655   | 668 | 681 | 694 | 706 | 719 | 732 | 744 | 757 | 769 | 1 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 |
| 345 | 782   | 794 | 807 | 820 | 832 | 845 | 857 | 870 | 882 | 895 | 1 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 |
| 346 | 908   | 920 | 933 | 945 | 958 | 970 | 983 | 995 | 008 | 020 | 1 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 |
| 347 | 54033 | 045 | 058 | 070 | 083 | 095 | 108 | 120 | 133 | 145 | 1 | 2 | 4 | 5 | 6 | 8 | 9 | 10 | 11 |
| 348 | 158   | 170 | 183 | 195 | 208 | 220 | 233 | 245 | 258 | 270 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 |
| 349 | 283   | 295 | 308 | 320 | 332 | 345 | 357 | 369 | 382 | 394 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 |
| 350 | 407   | 419 | 432 | 444 | 456 | 469 | 481 | 494 | 506 | 518 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 |
| 351 | 531   | 543 | 555 | 568 | 580 | 593 | 605 | 617 | 630 | 642 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 |
| 352 | 654   | 667 | 679 | 691 | 704 | 716 | 728 | 741 | 753 | 765 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 |
| 353 | 777   | 790 | 802 | 814 | 827 | 839 | 851 | 864 | 876 | 888 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 |
| 354 | 900   | 913 | 925 | 937 | 949 | 962 | 974 | 986 | 998 | 011 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 |
| 355 | 55023 | 035 | 047 | 060 | 072 | 084 | 096 | 108 | 121 | 133 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 |
| 356 | 145   | 157 | 169 | 182 | 194 | 206 | 218 | 230 | 242 | 255 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 |
| 357 | 267   | 279 | 291 | 303 | 315 | 328 | 340 | 352 | 364 | 376 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 |
| 358 | 388   | 400 | 413 | 425 | 437 | 449 | 461 | 473 | 485 | 497 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 10 | 11 |
| 359 | 509   | 522 | 534 | 546 | 558 | 570 | 582 | 594 | 606 | 618 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 10 | 11 |
| 360 | 630   | 642 | 654 | 666 | 678 | 691 | 703 | 715 | 727 | 739 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 10 | 11 |
| 361 | 751   | 763 | 775 | 787 | 799 | 811 | 823 | 835 | 847 | 859 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 10 | 11 |
| 362 | 871   | 883 | 895 | 907 | 919 | 931 | 943 | 955 | 967 | 979 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 10 | 11 |
| 363 | 991   | 003 | 015 | 027 | 038 | 050 | 062 | 074 | 086 | 098 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 10 | 11 |
| 364 | 56110 | 122 | 134 | 146 | 158 | 170 | 182 | 194 | 205 | 217 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 10 | 11 |
| 365 | 229   | 241 | 253 | 265 | 277 | 289 | 301 | 312 | 324 | 336 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 10 | 11 |
| 366 | 348   | 360 | 372 | 384 | 396 | 407 | 419 | 431 | 443 | 455 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 9  | 10 |
| 367 | 467   | 478 | 490 | 502 | 514 | 526 | 538 | 549 | 561 | 573 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 9  | 10 |
| 368 | 585   | 597 | 608 | 620 | 632 | 644 | 656 | 667 | 679 | 691 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 9  | 10 |
| 369 | 703   | 714 | 726 | 738 | 750 | 761 | 773 | 785 | 797 | 808 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 9  | 10 |
| 370 | 820   | 832 | 844 | 855 | 867 | 879 | 891 | 902 | 914 | 926 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 9  | 10 |
| 371 | 937   | 949 | 961 | 972 | 984 | 996 | 008 | 019 | 031 | 043 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 9  | 10 |
| 372 | 57054 | 066 | 078 | 089 | 101 | 113 | 124 | 136 | 148 | 159 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9  | 10 |
| 373 | 171   | 183 | 194 | 206 | 217 | 229 | 241 | 252 | 264 | 276 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9  | 10 |
| 374 | 287   | 299 | 310 | 322 | 334 | 345 | 357 | 368 | 380 | 392 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9  | 10 |
| 375 | 403   | 415 | 426 | 438 | 449 | 461 | 473 | 484 | 496 | 507 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9  | 10 |
| 376 | 519   | 530 | 542 | 553 | 565 | 576 | 588 | 600 | 611 | 623 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9  | 10 |
| 377 | 634   | 646 | 657 | 669 | 680 | 692 | 703 | 715 | 726 | 738 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9  | 10 |
| 378 | 749   | 761 | 772 | 784 | 795 | 807 | 818 | 830 | 841 | 852 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9  | 10 |
| 379 | 864   | 875 | 887 | 898 | 910 | 921 | 933 | 944 | 955 | 967 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9  | 10 |

380] Five-figure Logarithms—*continued.*

[.57

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9  |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|----|
| 380 | 57978 | 990 | 001 | 013 | 024 | 035 | 047 | 058 | 070 | 081 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 |
| 381 | 58092 | 104 | 115 | 127 | 138 | 149 | 161 | 172 | 184 | 195 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 |
| 382 | 206   | 218 | 229 | 240 | 252 | 263 | 274 | 286 | 297 | 309 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 |
| 383 | 320   | 331 | 343 | 354 | 355 | 377 | 388 | 399 | 410 | 422 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 |
| 384 | 433   | 444 | 456 | 467 | 478 | 490 | 501 | 512 | 524 | 535 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 |
| 385 | 545   | 557 | 569 | 580 | 591 | 602 | 614 | 625 | 636 | 647 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 |
| 386 | 659   | 670 | 681 | 692 | 704 | 715 | 726 | 737 | 749 | 760 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 |
| 387 | 771   | 782 | 794 | 805 | 816 | 827 | 838 | 850 | 861 | 872 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 |
| 388 | 883   | 894 | 906 | 917 | 928 | 939 | 950 | 961 | 973 | 984 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 |
| 389 | 995   | 006 | 017 | 028 | 040 | 051 | 062 | 073 | 084 | 095 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 |
| 390 | 59106 | 118 | 129 | 140 | 151 | 162 | 173 | 184 | 195 | 207 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 |
| 391 | 218   | 229 | 240 | 251 | 262 | 273 | 284 | 295 | 306 | 318 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 |
| 392 | 329   | 340 | 351 | 362 | 373 | 384 | 395 | 406 | 417 | 428 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 |
| 393 | 439   | 450 | 461 | 472 | 483 | 494 | 506 | 517 | 528 | 539 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 |
| 394 | 550   | 561 | 572 | 583 | 594 | 605 | 616 | 627 | 638 | 649 | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 |
| 395 | 660   | 671 | 682 | 693 | 704 | 715 | 726 | 737 | 748 | 759 | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 |
| 396 | 770   | 780 | 791 | 802 | 813 | 824 | 835 | 846 | 857 | 868 | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 |
| 397 | 879   | 890 | 901 | 912 | 923 | 934 | 945 | 956 | 966 | 977 | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 |
| 398 | 988   | 999 | 010 | 021 | 032 | 043 | 054 | 065 | 076 | 086 | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 |
| 399 | 60097 | 108 | 119 | 130 | 141 | 152 | 163 | 173 | 184 | 195 | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 |
| 400 | 206   | 217 | 228 | 239 | 249 | 260 | 271 | 282 | 293 | 304 | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 |
| 401 | 314   | 325 | 336 | 347 | 358 | 369 | 379 | 390 | 401 | 412 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 10 |
| 402 | 423   | 433 | 444 | 455 | 466 | 477 | 487 | 498 | 509 | 520 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 10 |
| 403 | 530   | 541 | 552 | 563 | 574 | 584 | 595 | 606 | 617 | 627 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 10 |
| 404 | 638   | 649 | 660 | 670 | 681 | 692 | 703 | 713 | 724 | 735 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 10 |
| 405 | 745   | 756 | 767 | 778 | 788 | 799 | 810 | 820 | 831 | 842 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 10 |
| 406 | 853   | 863 | 874 | 885 | 895 | 906 | 917 | 927 | 938 | 949 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 10 |
| 407 | 959   | 970 | 981 | 991 | 002 | 013 | 023 | 034 | 045 | 055 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 10 |
| 408 | 61066 | 077 | 087 | 098 | 109 | 119 | 130 | 140 | 151 | 162 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 10 |
| 409 | 172   | 183 | 194 | 204 | 215 | 225 | 236 | 247 | 257 | 268 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 |
| 410 | 278   | 289 | 299 | 310 | 321 | 331 | 342 | 352 | 363 | 374 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 |
| 411 | 384   | 395 | 405 | 416 | 426 | 437 | 448 | 458 | 469 | 479 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 |
| 412 | 490   | 500 | 511 | 521 | 532 | 542 | 553 | 563 | 574 | 584 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9  |
| 413 | 595   | 606 | 616 | 627 | 637 | 648 | 658 | 669 | 679 | 690 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9  |
| 414 | 700   | 711 | 721 | 732 | 742 | 752 | 763 | 773 | 784 | 794 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9  |
| 415 | 805   | 815 | 826 | 836 | 847 | 857 | 868 | 878 | 888 | 899 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9  |
| 416 | 909   | 920 | 930 | 941 | 951 | 961 | 972 | 982 | 993 | 003 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9  |
| 417 | 62014 | 024 | 034 | 045 | 055 | 065 | 076 | 086 | 097 | 107 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9  |
| 418 | 118   | 128 | 138 | 149 | 159 | 170 | 180 | 190 | 201 | 211 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9  |
| 419 | 221   | 232 | 242 | 252 | 263 | 273 | 284 | 294 | 304 | 315 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9  |

420 Five-figure Logarithms—*continued.* [62

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 420 | 62325 | 335 | 346 | 356 | 366 | 377 | 387 | 397 | 408 | 418 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 421 | 428   | 439 | 449 | 459 | 469 | 480 | 490 | 500 | 511 | 521 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 422 | 531   | 542 | 552 | 562 | 572 | 583 | 593 | 603 | 613 | 624 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 423 | 634   | 644 | 655 | 665 | 675 | 685 | 696 | 706 | 716 | 726 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 424 | 737   | 747 | 757 | 767 | 778 | 788 | 798 | 808 | 818 | 829 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 425 | 839   | 849 | 859 | 870 | 880 | 890 | 900 | 910 | 921 | 931 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 426 | 941   | 951 | 961 | 972 | 982 | 992 | 002 | 012 | 022 | 033 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 427 | 63043 | 053 | 063 | 073 | 083 | 094 | 104 | 114 | 124 | 134 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 428 | 144   | 155 | 165 | 175 | 185 | 195 | 205 | 215 | 225 | 236 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 429 | 246   | 256 | 266 | 276 | 286 | 296 | 306 | 317 | 327 | 337 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 430 | 347   | 357 | 367 | 377 | 387 | 397 | 407 | 417 | 428 | 438 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 431 | 448   | 458 | 468 | 478 | 488 | 498 | 508 | 518 | 528 | 538 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 432 | 548   | 558 | 568 | 579 | 589 | 599 | 609 | 619 | 629 | 639 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 433 | 649   | 659 | 669 | 679 | 689 | 699 | 709 | 719 | 729 | 739 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 434 | 749   | 759 | 769 | 779 | 789 | 799 | 809 | 819 | 829 | 839 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 435 | 849   | 859 | 869 | 879 | 889 | 899 | 909 | 919 | 929 | 939 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 436 | 949   | 959 | 969 | 979 | 988 | 998 | 008 | 018 | 028 | 038 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 437 | 64048 | 058 | 068 | 078 | 088 | 098 | 108 | 118 | 128 | 137 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 438 | 147   | 157 | 167 | 177 | 187 | 197 | 207 | 217 | 227 | 237 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 439 | 246   | 256 | 266 | 276 | 286 | 296 | 306 | 316 | 326 | 335 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 440 | 345   | 355 | 365 | 375 | 385 | 395 | 404 | 414 | 424 | 434 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 441 | 444   | 454 | 464 | 473 | 483 | 493 | 503 | 513 | 523 | 532 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 442 | 542   | 552 | 562 | 572 | 582 | 591 | 601 | 611 | 621 | 631 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 443 | 640   | 650 | 660 | 670 | 680 | 689 | 699 | 709 | 719 | 729 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 444 | 738   | 748 | 758 | 768 | 777 | 787 | 797 | 807 | 816 | 826 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 445 | 836   | 846 | 856 | 865 | 875 | 885 | 895 | 904 | 914 | 924 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 446 | 933   | 943 | 953 | 963 | 972 | 982 | 992 | 002 | 011 | 021 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 447 | 65031 | 040 | 050 | 060 | 070 | 079 | 089 | 099 | 108 | 118 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 448 | 128   | 137 | 147 | 157 | 167 | 176 | 186 | 196 | 205 | 215 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 449 | 225   | 234 | 244 | 254 | 263 | 273 | 283 | 292 | 302 | 312 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 450 | 321   | 331 | 341 | 350 | 360 | 369 | 379 | 388 | 398 | 408 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 451 | 418   | 428 | 437 | 447 | 456 | 466 | 475 | 485 | 495 | 504 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 452 | 514   | 523 | 533 | 543 | 552 | 562 | 571 | 581 | 591 | 600 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 453 | 610   | 619 | 629 | 639 | 648 | 657 | 667 | 676 | 686 | 696 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 454 | 706   | 715 | 725 | 734 | 744 | 753 | 763 | 772 | 782 | 792 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 455 | 801   | 811 | 820 | 830 | 839 | 849 | 858 | 868 | 877 | 887 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 456 | 896   | 906 | 916 | 925 | 935 | 944 | 954 | 963 | 973 | 982 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 457 | 992   | 001 | 011 | 020 | 030 | 039 | 049 | 058 | 068 | 077 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 458 | 66087 | 096 | 106 | 115 | 124 | 134 | 144 | 153 | 162 | 172 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 459 | 181   | 191 | 200 | 210 | 219 | 229 | 238 | 247 | 257 | 266 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

460] Five-figure Logarithms—*continued.*

[.66

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 460 | 66276 | 285 | 295 | 305 | 314 | 323 | 332 | 342 | 351 | 361 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 |
| 461 | 370   | 380 | 389 | 398 | 408 | 417 | 427 | 436 | 445 | 455 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 |
| 462 | 464   | 474 | 483 | 492 | 502 | 511 | 521 | 530 | 539 | 549 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 |
| 463 | 558   | 567 | 577 | 586 | 596 | 605 | 614 | 624 | 633 | 642 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 |
| 464 | 652   | 661 | 671 | 680 | 689 | 699 | 708 | 717 | 727 | 736 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 7 | 8 |
| 465 | 745   | 755 | 764 | 773 | 783 | 792 | 801 | 811 | 820 | 829 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 7 | 8 |
| 466 | 839   | 843 | 857 | 867 | 876 | 885 | 894 | 904 | 913 | 922 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 7 | 8 |
| 467 | 932   | 941 | 950 | 960 | 969 | 978 | 987 | 996 | 006 | 015 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 |
| 468 | 67025 | 034 | 043 | 052 | 062 | 071 | 080 | 089 | 099 | 108 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 |
| 469 | 117   | 127 | 136 | 145 | 154 | 164 | 173 | 182 | 191 | 200 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 |
| 470 | 210   | 219 | 228 | 237 | 247 | 256 | 265 | 274 | 284 | 293 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 |
| 471 | 302   | 311 | 321 | 330 | 339 | 348 | 357 | 367 | 376 | 385 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 |
| 472 | 394   | 403 | 413 | 422 | 431 | 440 | 449 | 459 | 468 | 477 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 |
| 473 | 486   | 495 | 504 | 514 | 523 | 532 | 541 | 550 | 560 | 569 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 474 | 578   | 587 | 596 | 605 | 614 | 624 | 633 | 642 | 651 | 660 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 475 | 669   | 678 | 688 | 697 | 706 | 715 | 724 | 733 | 742 | 752 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 476 | 761   | 770 | 779 | 788 | 797 | 806 | 815 | 825 | 834 | 843 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 477 | 852   | 861 | 870 | 879 | 888 | 897 | 906 | 915 | 925 | 934 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 478 | 943   | 952 | 961 | 970 | 979 | 988 | 997 | 006 | 015 | 024 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 479 | 68034 | 043 | 052 | 061 | 070 | 079 | 088 | 097 | 106 | 115 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 480 | 124   | 133 | 142 | 151 | 160 | 169 | 178 | 187 | 196 | 205 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 481 | 215   | 224 | 233 | 242 | 251 | 260 | 269 | 278 | 287 | 296 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 482 | 305   | 314 | 323 | 332 | 341 | 350 | 359 | 368 | 377 | 386 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 483 | 395   | 404 | 413 | 422 | 431 | 440 | 449 | 458 | 467 | 476 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 484 | 485   | 494 | 502 | 511 | 520 | 529 | 538 | 547 | 556 | 565 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 485 | 574   | 583 | 592 | 601 | 610 | 619 | 628 | 637 | 646 | 655 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 486 | 664   | 673 | 681 | 690 | 699 | 708 | 717 | 726 | 735 | 744 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 487 | 753   | 762 | 771 | 780 | 789 | 797 | 806 | 815 | 824 | 833 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 488 | 842   | 851 | 860 | 869 | 878 | 886 | 895 | 904 | 913 | 922 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 489 | 931   | 940 | 949 | 958 | 966 | 975 | 984 | 993 | 002 | 011 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 490 | 69020 | 028 | 037 | 046 | 055 | 064 | 073 | 082 | 090 | 099 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 491 | 108   | 117 | 126 | 135 | 144 | 152 | 161 | 170 | 179 | 188 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 492 | 197   | 205 | 214 | 223 | 232 | 241 | 249 | 258 | 267 | 276 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 493 | 285   | 293 | 302 | 311 | 320 | 329 | 338 | 346 | 355 | 364 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 494 | 373   | 381 | 390 | 399 | 408 | 417 | 425 | 434 | 443 | 452 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 495 | 461   | 469 | 478 | 487 | 496 | 504 | 513 | 522 | 531 | 539 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 496 | 548   | 557 | 566 | 574 | 583 | 592 | 601 | 609 | 618 | 627 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 497 | 636   | 644 | 653 | 662 | 671 | 679 | 688 | 697 | 705 | 714 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 498 | 723   | 732 | 740 | 749 | 758 | 767 | 775 | 784 | 793 | 801 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 499 | 810   | 819 | 827 | 836 | 845 | 854 | 862 | 871 | 880 | 888 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |

500] Five-figure Logarithms—*continued.* [·69

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 500 | 69897 | 906 | 914 | 923 | 932 | 940 | 949 | 958 | 966 | 975 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 501 | 984   | 992 | 001 | 010 | 018 | 027 | 036 | 044 | 053 | 062 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 502 | 70070 | 079 | 088 | 096 | 105 | 114 | 122 | 131 | 140 | 148 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 503 | 157   | 165 | 174 | 183 | 191 | 200 | 209 | 217 | 226 | 234 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 504 | 243   | 252 | 260 | 269 | 278 | 286 | 295 | 303 | 312 | 321 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 505 | 329   | 338 | 346 | 355 | 364 | 372 | 381 | 389 | 398 | 406 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 506 | 415   | 424 | 432 | 441 | 449 | 458 | 467 | 475 | 484 | 492 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 507 | 501   | 509 | 518 | 526 | 535 | 544 | 552 | 561 | 569 | 578 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 508 | 586   | 595 | 603 | 612 | 621 | 629 | 638 | 646 | 655 | 663 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 509 | 672   | 680 | 689 | 697 | 706 | 714 | 723 | 731 | 740 | 748 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 510 | 757   | 766 | 774 | 783 | 791 | 800 | 808 | 817 | 825 | 834 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 511 | 842   | 851 | 859 | 863 | 876 | 885 | 893 | 902 | 910 | 919 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 512 | 927   | 935 | 944 | 952 | 961 | 969 | 978 | 986 | 995 | 003 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 513 | 71012 | 020 | 029 | 037 | 046 | 054 | 062 | 071 | 079 | 088 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 514 | 096   | 105 | 113 | 122 | 130 | 139 | 147 | 155 | 164 | 172 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 515 | 181   | 189 | 198 | 206 | 214 | 223 | 231 | 240 | 248 | 257 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 516 | 265   | 273 | 282 | 290 | 299 | 307 | 315 | 324 | 332 | 341 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 517 | 349   | 357 | 366 | 374 | 383 | 391 | 399 | 408 | 416 | 425 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 518 | 433   | 441 | 450 | 458 | 466 | 475 | 483 | 492 | 500 | 508 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 519 | 517   | 525 | 533 | 542 | 550 | 559 | 567 | 575 | 584 | 592 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 520 | 600   | 609 | 617 | 625 | 634 | 642 | 650 | 659 | 667 | 675 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 521 | 684   | 692 | 700 | 709 | 717 | 725 | 734 | 742 | 750 | 759 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 522 | 767   | 775 | 784 | 792 | 800 | 809 | 817 | 825 | 834 | 842 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 523 | 850   | 858 | 867 | 875 | 883 | 892 | 900 | 908 | 917 | 925 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 524 | 933   | 941 | 950 | 958 | 966 | 975 | 983 | 991 | 999 | 008 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 525 | 72016 | 024 | 032 | 041 | 049 | 057 | 066 | 074 | 082 | 090 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 526 | 099   | 107 | 115 | 123 | 132 | 140 | 148 | 156 | 165 | 173 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 527 | 181   | 189 | 198 | 206 | 214 | 222 | 230 | 239 | 247 | 255 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 528 | 263   | 272 | 280 | 288 | 296 | 304 | 313 | 321 | 329 | 337 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 529 | 346   | 354 | 362 | 370 | 378 | 387 | 395 | 403 | 411 | 419 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 530 | 428   | 436 | 444 | 452 | 460 | 469 | 477 | 485 | 493 | 501 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 531 | 509   | 518 | 526 | 534 | 542 | 550 | 558 | 567 | 575 | 583 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 532 | 591   | 599 | 607 | 616 | 624 | 632 | 640 | 648 | 656 | 665 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 533 | 673   | 681 | 689 | 697 | 705 | 713 | 722 | 730 | 738 | 746 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 534 | 754   | 762 | 770 | 779 | 787 | 795 | 803 | 811 | 819 | 837 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 535 | 835   | 843 | 852 | 860 | 868 | 876 | 884 | 892 | 900 | 908 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 536 | 916   | 925 | 933 | 941 | 949 | 957 | 965 | 973 | 981 | 989 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 537 | 997   | 006 | 014 | 022 | 030 | 038 | 046 | 054 | 062 | 070 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 538 | 73078 | 086 | 094 | 102 | 111 | 119 | 127 | 135 | 143 | 151 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 539 | 159   | 167 | 175 | 183 | 191 | 199 | 207 | 215 | 223 | 231 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |

540] Five-figure Logarithms—*continued.* [73

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 540 | 73239 | 247 | 255 | 264 | 272 | 280 | 288 | 296 | 304 | 312 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 541 | 320   | 328 | 336 | 344 | 352 | 360 | 368 | 376 | 384 | 392 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 542 | 400   | 408 | 416 | 424 | 432 | 440 | 448 | 456 | 464 | 472 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 543 | 480   | 488 | 496 | 504 | 512 | 520 | 528 | 536 | 544 | 552 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 544 | 560   | 568 | 576 | 584 | 592 | 600 | 608 | 616 | 624 | 632 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 545 | 640   | 648 | 656 | 664 | 672 | 679 | 687 | 695 | 703 | 711 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 546 | 719   | 727 | 735 | 743 | 751 | 759 | 767 | 775 | 783 | 791 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 547 | 799   | 807 | 815 | 823 | 830 | 838 | 846 | 854 | 862 | 870 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 548 | 878   | 886 | 894 | 902 | 910 | 918 | 926 | 933 | 941 | 949 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 549 | 957   | 965 | 973 | 981 | 989 | 997 | 005 | 013 | 020 | 028 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 550 | 74036 | 044 | 052 | 060 | 068 | 076 | 084 | 092 | 099 | 107 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 551 | 115   | 123 | 131 | 139 | 147 | 155 | 162 | 170 | 178 | 186 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 552 | 194   | 202 | 210 | 218 | 225 | 233 | 241 | 249 | 257 | 265 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 553 | 273   | 280 | 288 | 296 | 304 | 312 | 320 | 327 | 335 | 343 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 554 | 351   | 359 | 367 | 374 | 382 | 390 | 398 | 406 | 414 | 421 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 555 | 429   | 437 | 445 | 453 | 461 | 468 | 476 | 484 | 492 | 500 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 556 | 507   | 515 | 523 | 531 | 539 | 547 | 554 | 562 | 570 | 578 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 557 | 586   | 593 | 601 | 609 | 617 | 624 | 632 | 640 | 648 | 656 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 558 | 663   | 671 | 679 | 687 | 695 | 702 | 710 | 718 | 726 | 733 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 559 | 741   | 749 | 757 | 764 | 772 | 780 | 788 | 796 | 803 | 811 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 560 | 819   | 827 | 834 | 842 | 850 | 858 | 865 | 873 | 881 | 889 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 561 | 896   | 904 | 912 | 920 | 927 | 935 | 943 | 950 | 958 | 966 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 562 | 974   | 981 | 989 | 997 | 005 | 012 | 020 | 028 | 035 | 043 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 563 | 75051 | 059 | 066 | 074 | 082 | 089 | 097 | 105 | 113 | 120 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 564 | 128   | 136 | 143 | 151 | 159 | 166 | 174 | 182 | 189 | 197 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 565 | 205   | 213 | 220 | 228 | 236 | 243 | 251 | 259 | 266 | 274 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 566 | 282   | 289 | 297 | 305 | 312 | 320 | 328 | 335 | 343 | 351 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 567 | 358   | 366 | 374 | 381 | 389 | 397 | 404 | 412 | 420 | 427 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 568 | 435   | 442 | 450 | 458 | 465 | 473 | 481 | 488 | 496 | 504 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 569 | 511   | 519 | 526 | 534 | 542 | 549 | 557 | 565 | 572 | 580 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 570 | 587   | 595 | 603 | 610 | 618 | 626 | 633 | 641 | 648 | 656 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 571 | 664   | 671 | 679 | 686 | 694 | 702 | 709 | 717 | 724 | 732 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 572 | 740   | 747 | 755 | 762 | 770 | 778 | 785 | 793 | 800 | 808 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 573 | 815   | 823 | 831 | 838 | 846 | 853 | 861 | 868 | 876 | 884 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 574 | 891   | 899 | 906 | 914 | 921 | 929 | 937 | 944 | 952 | 959 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 575 | 967   | 974 | 982 | 989 | 997 | 005 | 012 | 020 | 027 | 035 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 576 | 76042 | 050 | 057 | 065 | 072 | 080 | 087 | 095 | 103 | 110 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 577 | 118   | 125 | 133 | 140 | 148 | 155 | 163 | 170 | 178 | 185 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 578 | 193   | 200 | 208 | 215 | 223 | 230 | 238 | 245 | 253 | 260 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 579 | 268   | 275 | 283 | 290 | 298 | 305 | 313 | 320 | 328 | 335 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |



580] Five-figure Logarithms—*continued.*

[76

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 580 | 76343 | 350 | 358 | 365 | 373 | 380 | 388 | 395 | 403 | 410 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 581 | 418   | 425 | 433 | 440 | 448 | 455 | 462 | 470 | 477 | 485 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 582 | 492   | 500 | 507 | 515 | 522 | 530 | 537 | 544 | 552 | 559 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 583 | 567   | 574 | 582 | 589 | 597 | 604 | 612 | 619 | 626 | 634 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 584 | 641   | 649 | 656 | 664 | 671 | 678 | 686 | 693 | 701 | 708 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 585 | 716   | 723 | 730 | 738 | 745 | 753 | 760 | 768 | 775 | 782 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 586 | 790   | 797 | 805 | 812 | 819 | 827 | 834 | 842 | 849 | 856 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 587 | 864   | 871 | 879 | 886 | 893 | 901 | 908 | 916 | 923 | 930 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 588 | 938   | 945 | 952 | 960 | 967 | 975 | 982 | 989 | 997 | 004 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 589 | 77012 | 019 | 026 | 034 | 041 | 048 | 056 | 063 | 070 | 078 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 590 | 085   | 093 | 100 | 107 | 115 | 122 | 129 | 137 | 144 | 151 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 591 | 159   | 166 | 173 | 181 | 188 | 195 | 203 | 210 | 218 | 225 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 592 | 232   | 240 | 247 | 254 | 262 | 269 | 276 | 283 | 291 | 298 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 593 | 305   | 313 | 320 | 327 | 335 | 342 | 349 | 357 | 364 | 371 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 594 | 379   | 386 | 393 | 401 | 408 | 415 | 422 | 430 | 437 | 444 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 595 | 452   | 459 | 466 | 474 | 481 | 488 | 495 | 503 | 510 | 517 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 596 | 525   | 532 | 539 | 546 | 554 | 561 | 568 | 576 | 583 | 590 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 597 | 597   | 605 | 612 | 619 | 627 | 634 | 641 | 648 | 656 | 663 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 598 | 670   | 677 | 685 | 692 | 699 | 706 | 714 | 721 | 728 | 735 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 599 | 743   | 750 | 757 | 764 | 772 | 779 | 786 | 793 | 801 | 808 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 600 | 815   | 822 | 830 | 837 | 844 | 851 | 859 | 866 | 873 | 880 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 601 | 887   | 895 | 902 | 909 | 916 | 924 | 931 | 938 | 945 | 952 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 602 | 960   | 967 | 974 | 981 | 988 | 996 | 003 | 010 | 017 | 024 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 603 | 78032 | 039 | 046 | 053 | 061 | 068 | 075 | 082 | 089 | 096 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 604 | 104   | 111 | 118 | 125 | 132 | 140 | 147 | 154 | 161 | 168 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 605 | 176   | 183 | 190 | 197 | 204 | 211 | 219 | 226 | 233 | 240 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 606 | 247   | 254 | 262 | 269 | 276 | 283 | 290 | 297 | 305 | 312 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 607 | 319   | 326 | 333 | 340 | 347 | 355 | 362 | 369 | 376 | 383 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 608 | 390   | 398 | 405 | 412 | 419 | 426 | 433 | 440 | 447 | 455 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 609 | 462   | 469 | 476 | 483 | 490 | 497 | 504 | 512 | 519 | 526 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 610 | 533   | 540 | 547 | 554 | 561 | 569 | 576 | 583 | 590 | 597 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 611 | 604   | 611 | 618 | 625 | 633 | 640 | 647 | 654 | 661 | 668 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 612 | 675   | 682 | 689 | 696 | 704 | 711 | 718 | 725 | 732 | 739 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 613 | 746   | 753 | 760 | 767 | 774 | 781 | 789 | 796 | 803 | 810 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 614 | 817   | 824 | 831 | 838 | 845 | 852 | 859 | 866 | 873 | 880 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 615 | 888   | 895 | 902 | 909 | 916 | 923 | 930 | 937 | 944 | 951 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 616 | 958   | 965 | 972 | 979 | 986 | 993 | 000 | 007 | 014 | 021 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 617 | 79029 | 036 | 043 | 050 | 057 | 064 | 071 | 078 | 085 | 092 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 618 | 099   | 106 | 113 | 120 | 127 | 134 | 141 | 148 | 155 | 162 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 619 | 169   | 176 | 183 | 190 | 197 | 204 | 211 | 218 | 225 | 232 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |



620] Five-figure Logarithms—*continued.*

[79

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 620 | 79239 | 246 | 253 | 260 | 267 | 274 | 281 | 288 | 295 | 302 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 621 | 309   | 316 | 323 | 330 | 337 | 344 | 351 | 358 | 365 | 372 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 622 | 379   | 386 | 393 | 400 | 407 | 414 | 421 | 428 | 435 | 442 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 623 | 449   | 456 | 463 | 470 | 477 | 484 | 491 | 498 | 505 | 512 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 6 |
| 624 | 518   | 525 | 532 | 539 | 546 | 553 | 560 | 567 | 574 | 581 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 6 |
| 625 | 588   | 595 | 602 | 609 | 616 | 623 | 630 | 637 | 644 | 650 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 6 |
| 626 | 657   | 664 | 671 | 678 | 685 | 692 | 699 | 706 | 713 | 720 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 6 |
| 627 | 727   | 734 | 741 | 748 | 754 | 761 | 768 | 775 | 782 | 789 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 6 |
| 628 | 796   | 803 | 810 | 817 | 824 | 831 | 837 | 844 | 851 | 858 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 6 |
| 629 | 865   | 872 | 879 | 886 | 893 | 900 | 906 | 913 | 920 | 927 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 6 |
| 630 | 934   | 941 | 948 | 955 | 962 | 969 | 975 | 982 | 989 | 996 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 6 |
| 631 | 80003 | 010 | 017 | 024 | 030 | 037 | 044 | 051 | 058 | 065 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 6 |
| 632 | 072   | 079 | 085 | 092 | 099 | 106 | 113 | 120 | 127 | 134 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 633 | 140   | 147 | 154 | 161 | 168 | 175 | 182 | 188 | 195 | 202 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 634 | 209   | 216 | 223 | 229 | 236 | 243 | 250 | 257 | 264 | 271 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 635 | 277   | 284 | 291 | 298 | 305 | 312 | 318 | 325 | 332 | 339 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 636 | 346   | 353 | 359 | 366 | 373 | 380 | 387 | 393 | 400 | 407 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 637 | 414   | 421 | 428 | 434 | 441 | 448 | 455 | 462 | 468 | 475 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 638 | 482   | 489 | 496 | 502 | 509 | 516 | 523 | 530 | 536 | 543 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 639 | 550   | 557 | 564 | 570 | 577 | 584 | 591 | 598 | 604 | 611 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 640 | 618   | 625 | 632 | 638 | 645 | 652 | 659 | 665 | 672 | 679 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 641 | 686   | 693 | 699 | 706 | 713 | 720 | 726 | 733 | 740 | 747 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 642 | 754   | 760 | 767 | 774 | 781 | 787 | 794 | 801 | 808 | 814 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 643 | 821   | 828 | 835 | 841 | 848 | 855 | 862 | 868 | 875 | 882 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 644 | 889   | 895 | 902 | 909 | 916 | 922 | 929 | 936 | 942 | 949 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 645 | 956   | 963 | 969 | 976 | 983 | 990 | 996 | 003 | 010 | 017 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 646 | 81023 | 030 | 037 | 043 | 050 | 057 | 064 | 070 | 077 | 084 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 647 | 090   | 097 | 104 | 111 | 117 | 124 | 131 | 137 | 144 | 151 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 648 | 158   | 164 | 171 | 178 | 184 | 191 | 198 | 204 | 211 | 218 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 649 | 224   | 231 | 238 | 245 | 251 | 258 | 265 | 271 | 278 | 285 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 650 | 291   | 298 | 305 | 311 | 318 | 325 | 331 | 338 | 345 | 351 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 651 | 358   | 365 | 371 | 378 | 385 | 391 | 398 | 405 | 411 | 418 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 652 | 425   | 431 | 438 | 445 | 451 | 458 | 465 | 471 | 478 | 485 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 653 | 491   | 498 | 505 | 511 | 518 | 525 | 531 | 538 | 544 | 551 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 654 | 558   | 564 | 571 | 578 | 584 | 591 | 598 | 604 | 611 | 618 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 655 | 624   | 631 | 637 | 644 | 651 | 657 | 664 | 671 | 677 | 684 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 656 | 690   | 697 | 704 | 710 | 717 | 723 | 730 | 737 | 743 | 750 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 657 | 757   | 763 | 770 | 776 | 783 | 790 | 796 | 803 | 809 | 816 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 658 | 823   | 829 | 836 | 842 | 849 | 856 | 862 | 869 | 875 | 882 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 659 | 889   | 895 | 902 | 908 | 915 | 921 | 928 | 935 | 941 | 948 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |

660] Five-figure Logarithms—*continued.* [·81

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 660 | 81954 | 961 | 968 | 974 | 981 | 987 | 994 | 000 | 007 | 014 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 661 | 82020 | 027 | 033 | 040 | 046 | 053 | 060 | 066 | 073 | 079 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 662 | 086   | 092 | 099 | 105 | 112 | 119 | 125 | 132 | 138 | 145 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 663 | 151   | 158 | 164 | 171 | 177 | 184 | 191 | 197 | 204 | 210 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 664 | 217   | 223 | 230 | 236 | 243 | 250 | 256 | 263 | 269 | 276 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 665 | 282   | 289 | 295 | 302 | 308 | 315 | 321 | 328 | 334 | 341 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 666 | 347   | 354 | 360 | 367 | 374 | 380 | 387 | 393 | 400 | 406 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 667 | 413   | 419 | 426 | 432 | 439 | 445 | 452 | 458 | 465 | 471 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 668 | 478   | 484 | 491 | 497 | 504 | 510 | 517 | 523 | 530 | 536 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 669 | 543   | 549 | 556 | 562 | 569 | 575 | 582 | 588 | 595 | 601 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 670 | 607   | 614 | 620 | 627 | 633 | 640 | 646 | 653 | 659 | 666 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 671 | 672   | 679 | 685 | 692 | 698 | 705 | 711 | 718 | 724 | 730 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 672 | 737   | 743 | 750 | 756 | 763 | 769 | 776 | 782 | 789 | 795 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 673 | 802   | 808 | 814 | 821 | 827 | 834 | 840 | 847 | 853 | 860 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 674 | 866   | 872 | 879 | 885 | 892 | 898 | 905 | 911 | 918 | 924 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 675 | 930   | 937 | 943 | 950 | 956 | 963 | 969 | 975 | 982 | 988 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 676 | 995   | 001 | 008 | 014 | 020 | 027 | 033 | 040 | 046 | 052 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 677 | 83059 | 065 | 072 | 078 | 085 | 091 | 097 | 104 | 110 | 117 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 678 | 123   | 129 | 136 | 142 | 149 | 155 | 161 | 168 | 174 | 181 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 679 | 187   | 193 | 200 | 206 | 213 | 219 | 225 | 232 | 238 | 244 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 680 | 251   | 257 | 264 | 270 | 276 | 283 | 289 | 296 | 302 | 308 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 681 | 315   | 321 | 327 | 334 | 340 | 347 | 353 | 359 | 366 | 372 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 682 | 378   | 385 | 391 | 398 | 404 | 410 | 417 | 423 | 429 | 436 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 683 | 442   | 448 | 455 | 461 | 468 | 474 | 480 | 487 | 493 | 499 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 684 | 506   | 512 | 518 | 525 | 531 | 537 | 544 | 550 | 556 | 563 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 685 | 569   | 575 | 582 | 588 | 594 | 601 | 607 | 613 | 620 | 626 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 686 | 632   | 639 | 645 | 651 | 658 | 664 | 670 | 677 | 683 | 689 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 687 | 696   | 702 | 708 | 715 | 721 | 727 | 734 | 740 | 746 | 753 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 688 | 759   | 765 | 771 | 778 | 784 | 790 | 797 | 803 | 809 | 816 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 689 | 822   | 828 | 835 | 841 | 847 | 853 | 860 | 866 | 872 | 879 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 690 | 885   | 891 | 898 | 904 | 910 | 916 | 923 | 929 | 935 | 942 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 691 | 948   | 954 | 960 | 967 | 973 | 979 | 986 | 992 | 998 | 004 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 692 | 84011 | 017 | 023 | 029 | 036 | 042 | 048 | 055 | 061 | 067 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 693 | 073   | 080 | 086 | 092 | 098 | 105 | 111 | 117 | 123 | 130 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 694 | 136   | 142 | 148 | 155 | 161 | 167 | 173 | 180 | 186 | 192 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 695 | 198   | 205 | 211 | 217 | 223 | 230 | 236 | 242 | 248 | 255 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 696 | 261   | 267 | 273 | 280 | 286 | 292 | 298 | 305 | 311 | 317 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 697 | 323   | 330 | 336 | 342 | 348 | 354 | 361 | 367 | 373 | 379 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 698 | 386   | 392 | 398 | 404 | 410 | 417 | 423 | 429 | 435 | 442 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 699 | 448   | 454 | 460 | 466 | 473 | 479 | 485 | 491 | 497 | 504 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |

700] Five-figure Logarithms—*continued.*

[.84

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 700 | 84510 | 516 | 522 | 528 | 535 | 541 | 547 | 553 | 559 | 566 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 701 | 572   | 578 | 584 | 590 | 597 | 603 | 609 | 615 | 621 | 628 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 702 | 634   | 640 | 646 | 652 | 658 | 665 | 671 | 677 | 683 | 689 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 703 | 696   | 702 | 708 | 714 | 720 | 726 | 733 | 739 | 745 | 751 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 704 | 757   | 763 | 770 | 776 | 782 | 788 | 794 | 800 | 807 | 813 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 705 | 819   | 825 | 831 | 837 | 844 | 850 | 856 | 862 | 868 | 874 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 706 | 880   | 887 | 893 | 899 | 905 | 911 | 917 | 924 | 930 | 936 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 707 | 942   | 948 | 954 | 960 | 967 | 973 | 979 | 985 | 991 | 997 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 708 | 85003 | 009 | 016 | 022 | 028 | 034 | 040 | 046 | 052 | 058 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 709 | 065   | 071 | 077 | 083 | 089 | 095 | 101 | 107 | 114 | 120 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 710 | 126   | 132 | 138 | 144 | 150 | 156 | 163 | 169 | 175 | 181 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 711 | 187   | 193 | 199 | 205 | 211 | 217 | 224 | 230 | 236 | 242 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 712 | 248   | 254 | 260 | 266 | 272 | 278 | 285 | 291 | 297 | 303 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 713 | 309   | 315 | 321 | 327 | 333 | 339 | 345 | 352 | 358 | 364 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 714 | 370   | 376 | 382 | 388 | 394 | 400 | 406 | 412 | 418 | 425 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 715 | 431   | 437 | 443 | 449 | 455 | 451 | 467 | 473 | 479 | 485 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 716 | 491   | 497 | 503 | 510 | 516 | 522 | 528 | 534 | 540 | 546 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 717 | 552   | 558 | 564 | 570 | 576 | 582 | 588 | 594 | 600 | 606 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 718 | 612   | 618 | 625 | 631 | 637 | 643 | 649 | 655 | 661 | 667 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 719 | 673   | 679 | 685 | 691 | 697 | 703 | 709 | 715 | 721 | 727 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 720 | 733   | 739 | 745 | 751 | 757 | 763 | 769 | 775 | 781 | 788 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 721 | 794   | 800 | 806 | 812 | 818 | 824 | 830 | 836 | 842 | 848 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 722 | 854   | 860 | 866 | 872 | 878 | 884 | 890 | 896 | 902 | 908 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 723 | 914   | 920 | 926 | 932 | 938 | 944 | 950 | 956 | 962 | 968 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 724 | 974   | 980 | 986 | 992 | 998 | 004 | 010 | 016 | 022 | 028 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 725 | 86034 | 040 | 046 | 052 | 058 | 064 | 070 | 076 | 082 | 088 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 726 | 094   | 100 | 106 | 112 | 118 | 124 | 130 | 136 | 141 | 147 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 727 | 153   | 159 | 165 | 171 | 177 | 183 | 189 | 195 | 201 | 207 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 728 | 213   | 219 | 225 | 231 | 237 | 243 | 249 | 255 | 261 | 267 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 729 | 273   | 279 | 285 | 291 | 297 | 303 | 308 | 314 | 320 | 326 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 730 | 332   | 338 | 344 | 350 | 356 | 362 | 368 | 374 | 380 | 386 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 731 | 392   | 398 | 404 | 410 | 416 | 421 | 427 | 433 | 439 | 445 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 732 | 451   | 457 | 463 | 469 | 475 | 481 | 487 | 493 | 499 | 504 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 733 | 510   | 516 | 522 | 528 | 534 | 540 | 546 | 552 | 558 | 564 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 734 | 570   | 576 | 581 | 587 | 593 | 599 | 605 | 611 | 617 | 623 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 735 | 629   | 635 | 641 | 646 | 652 | 658 | 664 | 670 | 676 | 682 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 736 | 688   | 694 | 700 | 705 | 711 | 717 | 723 | 729 | 735 | 741 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 737 | 747   | 753 | 759 | 764 | 770 | 776 | 782 | 788 | 794 | 800 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 738 | 806   | 812 | 817 | 823 | 829 | 835 | 841 | 847 | 853 | 859 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 739 | 864   | 870 | 876 | 882 | 888 | 894 | 900 | 906 | 911 | 917 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |

740] Five-figure Logarithms—*continued.* [86

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 740 | 86923 | 929 | 935 | 941 | 947 | 953 | 958 | 964 | 970 | 976 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 741 | 982   | 988 | 994 | 999 | 005 | 011 | 017 | 023 | 029 | 035 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 742 | 87040 | 046 | 052 | 058 | 064 | 070 | 075 | 081 | 087 | 093 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 743 | 099   | 105 | 111 | 116 | 122 | 128 | 134 | 140 | 146 | 151 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 744 | 157   | 163 | 169 | 175 | 181 | 186 | 192 | 198 | 204 | 210 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 745 | 216   | 221 | 227 | 233 | 239 | 245 | 251 | 256 | 262 | 268 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 746 | 274   | 280 | 286 | 291 | 297 | 303 | 309 | 315 | 320 | 326 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 747 | 332   | 338 | 344 | 350 | 355 | 361 | 367 | 373 | 379 | 384 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 748 | 390   | 396 | 402 | 408 | 413 | 419 | 425 | 431 | 437 | 442 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 749 | 448   | 454 | 460 | 466 | 471 | 477 | 483 | 489 | 495 | 500 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 750 | 506   | 512 | 518 | 523 | 529 | 535 | 541 | 547 | 552 | 558 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 751 | 564   | 570 | 576 | 581 | 587 | 593 | 599 | 604 | 610 | 616 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 752 | 622   | 628 | 633 | 639 | 645 | 651 | 656 | 662 | 668 | 674 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 753 | 680   | 685 | 691 | 697 | 703 | 708 | 714 | 720 | 726 | 731 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 754 | 737   | 743 | 749 | 754 | 760 | 766 | 772 | 777 | 783 | 789 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 755 | 795   | 800 | 806 | 812 | 818 | 823 | 829 | 835 | 841 | 846 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 756 | 852   | 858 | 864 | 869 | 875 | 881 | 887 | 892 | 898 | 904 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 757 | 910   | 915 | 921 | 927 | 933 | 938 | 944 | 950 | 955 | 961 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 758 | 967   | 973 | 978 | 984 | 990 | 996 | 001 | 007 | 013 | 018 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 759 | 88024 | 030 | 036 | 041 | 047 | 053 | 058 | 064 | 070 | 076 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 760 | 082   | 087 | 093 | 098 | 104 | 110 | 116 | 121 | 127 | 133 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 761 | 138   | 144 | 150 | 156 | 161 | 167 | 173 | 178 | 184 | 190 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 762 | 196   | 201 | 207 | 213 | 218 | 224 | 230 | 235 | 241 | 247 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 763 | 252   | 258 | 264 | 270 | 275 | 281 | 287 | 292 | 298 | 304 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 764 | 309   | 315 | 321 | 326 | 332 | 338 | 343 | 349 | 355 | 360 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 765 | 366   | 372 | 378 | 383 | 389 | 395 | 400 | 406 | 412 | 417 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 766 | 423   | 429 | 434 | 440 | 446 | 451 | 457 | 463 | 468 | 474 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 767 | 480   | 485 | 491 | 497 | 502 | 508 | 514 | 519 | 525 | 530 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 768 | 536   | 542 | 547 | 553 | 559 | 564 | 570 | 576 | 581 | 587 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 769 | 593   | 598 | 604 | 610 | 615 | 621 | 627 | 632 | 638 | 643 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 770 | 649   | 655 | 660 | 666 | 672 | 677 | 683 | 689 | 694 | 700 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 771 | 705   | 711 | 717 | 722 | 728 | 734 | 739 | 745 | 750 | 756 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 772 | 762   | 767 | 773 | 779 | 784 | 790 | 795 | 801 | 807 | 812 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 773 | 818   | 824 | 829 | 835 | 840 | 846 | 852 | 857 | 863 | 868 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 774 | 874   | 880 | 885 | 891 | 897 | 902 | 908 | 913 | 919 | 925 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 775 | 930   | 936 | 941 | 947 | 953 | 958 | 964 | 969 | 975 | 981 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 776 | 986   | 992 | 997 | 003 | 009 | 014 | 020 | 025 | 031 | 037 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 777 | 89042 | 048 | 053 | 059 | 064 | 070 | 076 | 081 | 087 | 092 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 778 | 098   | 104 | 109 | 115 | 120 | 126 | 131 | 137 | 143 | 148 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 779 | 154   | 159 | 165 | 170 | 176 | 182 | 187 | 193 | 198 | 204 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |

780] Five-figure Logarithms—*continued.*

[.89

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 780 | 89209 | 215 | 221 | 226 | 232 | 237 | 243 | 248 | 254 | 260 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 781 | 265   | 271 | 276 | 282 | 287 | 293 | 298 | 304 | 310 | 315 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 782 | 321   | 326 | 332 | 337 | 343 | 348 | 354 | 360 | 365 | 371 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 783 | 376   | 382 | 387 | 393 | 398 | 404 | 409 | 415 | 421 | 426 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 784 | 432   | 437 | 443 | 448 | 454 | 459 | 465 | 470 | 476 | 481 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 785 | 487   | 493 | 498 | 504 | 509 | 515 | 520 | 526 | 531 | 537 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 786 | 542   | 548 | 553 | 559 | 564 | 570 | 575 | 581 | 586 | 592 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 787 | 597   | 603 | 609 | 614 | 620 | 625 | 631 | 636 | 642 | 647 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 788 | 653   | 658 | 664 | 669 | 675 | 680 | 686 | 691 | 697 | 702 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 789 | 708   | 713 | 719 | 724 | 730 | 735 | 741 | 746 | 752 | 757 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 790 | 763   | 768 | 774 | 779 | 785 | 790 | 796 | 801 | 807 | 812 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 791 | 818   | 823 | 829 | 834 | 840 | 845 | 851 | 856 | 862 | 867 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 792 | 873   | 878 | 883 | 889 | 894 | 900 | 905 | 911 | 916 | 922 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 793 | 927   | 933 | 938 | 944 | 949 | 955 | 960 | 966 | 971 | 977 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 794 | 982   | 988 | 993 | 998 | 004 | 009 | 015 | 020 | 026 | 031 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 795 | 90037 | 042 | 048 | 053 | 059 | 064 | 069 | 075 | 080 | 086 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 796 | 091   | 097 | 102 | 108 | 113 | 119 | 124 | 129 | 135 | 140 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 797 | 146   | 151 | 157 | 162 | 168 | 173 | 179 | 184 | 189 | 195 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 798 | 200   | 206 | 211 | 217 | 222 | 227 | 233 | 238 | 244 | 249 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 799 | 255   | 260 | 266 | 271 | 276 | 282 | 287 | 293 | 298 | 304 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 800 | 309   | 314 | 320 | 325 | 331 | 336 | 342 | 347 | 352 | 358 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 801 | 363   | 369 | 374 | 380 | 385 | 390 | 396 | 401 | 407 | 412 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 802 | 417   | 423 | 428 | 434 | 439 | 444 | 450 | 455 | 461 | 466 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 803 | 472   | 477 | 482 | 488 | 493 | 499 | 504 | 509 | 515 | 520 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 804 | 526   | 531 | 536 | 542 | 547 | 553 | 558 | 563 | 569 | 574 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 805 | 580   | 585 | 590 | 596 | 601 | 607 | 612 | 617 | 623 | 628 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 806 | 634   | 639 | 644 | 650 | 655 | 660 | 666 | 671 | 677 | 682 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 807 | 687   | 693 | 698 | 704 | 709 | 714 | 720 | 725 | 730 | 736 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 808 | 741   | 747 | 752 | 757 | 763 | 768 | 773 | 779 | 784 | 789 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 809 | 795   | 800 | 806 | 811 | 816 | 822 | 827 | 832 | 838 | 843 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 810 | 849   | 854 | 859 | 865 | 870 | 875 | 881 | 886 | 891 | 897 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 811 | 902   | 907 | 913 | 918 | 924 | 929 | 934 | 940 | 945 | 950 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 812 | 956   | 961 | 966 | 972 | 977 | 982 | 988 | 993 | 998 | 004 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 813 | 91009 | 014 | 020 | 025 | 030 | 035 | 041 | 046 | 052 | 057 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 814 | 062   | 068 | 073 | 078 | 084 | 089 | 094 | 100 | 105 | 110 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 815 | 116   | 121 | 126 | 132 | 137 | 142 | 148 | 153 | 158 | 164 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 816 | 169   | 174 | 180 | 185 | 190 | 196 | 201 | 206 | 212 | 217 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 817 | 222   | 228 | 233 | 238 | 243 | 249 | 254 | 259 | 265 | 270 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 818 | 275   | 281 | 286 | 291 | 297 | 302 | 307 | 312 | 318 | 323 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 819 | 328   | 334 | 339 | 344 | 350 | 355 | 360 | 365 | 371 | 376 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |

820] Five-figure Logarithms—*continued.*

[91

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 820 | 91381 | 387 | 392 | 397 | 403 | 408 | 413 | 418 | 424 | 429 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 821 | 434   | 440 | 445 | 450 | 455 | 461 | 466 | 471 | 477 | 482 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 822 | 487   | 492 | 498 | 503 | 508 | 514 | 519 | 524 | 529 | 535 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 823 | 540   | 545 | 551 | 556 | 561 | 566 | 572 | 577 | 582 | 587 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 824 | 593   | 598 | 603 | 609 | 614 | 619 | 624 | 630 | 635 | 640 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 825 | 645   | 651 | 656 | 661 | 666 | 672 | 677 | 682 | 687 | 693 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 826 | 698   | 703 | 709 | 714 | 719 | 724 | 730 | 735 | 740 | 745 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 827 | 751   | 756 | 761 | 766 | 772 | 777 | 782 | 787 | 793 | 798 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 828 | 803   | 808 | 814 | 819 | 824 | 829 | 834 | 840 | 845 | 850 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 829 | 855   | 861 | 866 | 871 | 876 | 882 | 887 | 892 | 897 | 903 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 830 | 908   | 913 | 918 | 924 | 929 | 934 | 939 | 944 | 950 | 955 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 831 | 960   | 965 | 971 | 976 | 981 | 986 | 991 | 997 | 002 | 007 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 832 | 92012 | 018 | 023 | 028 | 033 | 038 | 044 | 049 | 054 | 059 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 833 | 065   | 070 | 075 | 080 | 085 | 091 | 096 | 101 | 106 | 111 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 834 | 117   | 122 | 127 | 132 | 137 | 143 | 148 | 153 | 158 | 163 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 835 | 169   | 174 | 179 | 184 | 189 | 195 | 200 | 205 | 210 | 215 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 836 | 221   | 226 | 231 | 236 | 241 | 247 | 252 | 257 | 262 | 267 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 837 | 273   | 278 | 283 | 288 | 293 | 298 | 304 | 309 | 314 | 319 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 838 | 324   | 330 | 335 | 340 | 345 | 350 | 355 | 361 | 366 | 371 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 839 | 376   | 381 | 387 | 392 | 397 | 402 | 407 | 412 | 418 | 423 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 840 | 428   | 433 | 438 | 443 | 449 | 454 | 459 | 464 | 469 | 474 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 841 | 480   | 485 | 490 | 495 | 500 | 505 | 511 | 516 | 521 | 526 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 842 | 531   | 536 | 542 | 547 | 552 | 557 | 562 | 567 | 572 | 578 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 843 | 583   | 588 | 593 | 598 | 603 | 609 | 614 | 619 | 624 | 629 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 844 | 634   | 639 | 645 | 650 | 655 | 660 | 665 | 670 | 675 | 681 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 845 | 686   | 691 | 696 | 701 | 706 | 711 | 716 | 722 | 727 | 732 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 846 | 737   | 742 | 747 | 752 | 758 | 763 | 768 | 773 | 778 | 783 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 847 | 788   | 793 | 799 | 804 | 809 | 814 | 819 | 824 | 829 | 834 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 848 | 840   | 845 | 850 | 855 | 860 | 865 | 870 | 875 | 881 | 886 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 849 | 891   | 896 | 901 | 906 | 911 | 916 | 921 | 927 | 932 | 937 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 850 | 942   | 947 | 952 | 957 | 962 | 967 | 973 | 978 | 983 | 988 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 851 | 993   | 998 | 003 | 008 | 013 | 018 | 024 | 029 | 034 | 039 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 852 | 93044 | 049 | 054 | 059 | 064 | 069 | 075 | 080 | 085 | 090 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 853 | 095   | 100 | 105 | 110 | 115 | 120 | 125 | 131 | 136 | 141 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 854 | 146   | 151 | 156 | 161 | 166 | 171 | 176 | 181 | 186 | 192 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 855 | 197   | 202 | 207 | 212 | 217 | 222 | 227 | 232 | 237 | 242 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 856 | 247   | 252 | 258 | 263 | 268 | 273 | 278 | 283 | 288 | 293 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 857 | 298   | 303 | 308 | 313 | 318 | 323 | 328 | 334 | 339 | 344 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 858 | 349   | 354 | 359 | 364 | 369 | 374 | 379 | 384 | 389 | 394 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 859 | 399   | 404 | 409 | 414 | 420 | 425 | 430 | 435 | 440 | 445 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |



860] Five-figure Logarithms—*continued.*

[93

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 860 | 93450 | 455 | 460 | 465 | 470 | 475 | 480 | 485 | 490 | 495 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 861 | 500   | 505 | 510 | 515 | 520 | 526 | 531 | 536 | 541 | 546 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 862 | 551   | 556 | 561 | 566 | 571 | 576 | 581 | 586 | 591 | 596 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 863 | 601   | 606 | 611 | 616 | 621 | 626 | 631 | 636 | 641 | 646 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 864 | 651   | 656 | 661 | 666 | 671 | 676 | 682 | 687 | 692 | 697 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 865 | 702   | 707 | 712 | 717 | 722 | 727 | 732 | 737 | 742 | 747 | 0 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 866 | 752   | 757 | 762 | 767 | 772 | 777 | 782 | 787 | 792 | 797 | 0 | 1 | 2 | 2 | 2 | 3 | 4 | 4 | 5 |
| 867 | 802   | 807 | 812 | 817 | 822 | 827 | 832 | 837 | 842 | 847 | 0 | 1 | 2 | 2 | 2 | 3 | 4 | 4 | 4 |
| 868 | 852   | 857 | 862 | 867 | 872 | 877 | 882 | 887 | 892 | 897 | 0 | 1 | 2 | 2 | 2 | 3 | 4 | 4 | 4 |
| 869 | 902   | 907 | 912 | 917 | 922 | 927 | 932 | 937 | 942 | 947 | 0 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 |
| 870 | 952   | 957 | 962 | 967 | 972 | 977 | 982 | 987 | 992 | 997 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 871 | 94002 | 007 | 012 | 017 | 022 | 027 | 032 | 037 | 042 | 047 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 872 | 052   | 057 | 062 | 067 | 072 | 077 | 082 | 086 | 091 | 096 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 873 | 101   | 106 | 111 | 116 | 121 | 126 | 131 | 136 | 141 | 146 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 874 | 151   | 156 | 161 | 166 | 171 | 176 | 181 | 186 | 191 | 196 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 875 | 201   | 206 | 211 | 216 | 221 | 226 | 231 | 236 | 240 | 245 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 876 | 250   | 255 | 260 | 265 | 270 | 275 | 280 | 285 | 290 | 295 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 877 | 300   | 305 | 310 | 315 | 320 | 325 | 330 | 335 | 340 | 344 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 878 | 349   | 354 | 359 | 364 | 369 | 374 | 379 | 384 | 389 | 394 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 879 | 399   | 404 | 409 | 414 | 419 | 424 | 429 | 433 | 438 | 443 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 880 | 448   | 453 | 458 | 463 | 468 | 473 | 478 | 483 | 488 | 493 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 881 | 498   | 503 | 507 | 512 | 517 | 522 | 527 | 532 | 537 | 542 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 882 | 547   | 552 | 557 | 562 | 567 | 571 | 576 | 581 | 586 | 591 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 883 | 596   | 601 | 606 | 611 | 616 | 621 | 626 | 630 | 635 | 640 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 884 | 645   | 650 | 655 | 660 | 665 | 670 | 675 | 680 | 685 | 689 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 885 | 694   | 699 | 704 | 709 | 714 | 719 | 724 | 729 | 734 | 738 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 886 | 743   | 748 | 753 | 758 | 763 | 768 | 773 | 778 | 783 | 787 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 887 | 792   | 797 | 802 | 807 | 812 | 817 | 822 | 827 | 832 | 836 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 888 | 841   | 846 | 851 | 856 | 861 | 866 | 871 | 876 | 880 | 885 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 889 | 890   | 895 | 900 | 905 | 910 | 915 | 919 | 924 | 929 | 934 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 890 | 939   | 944 | 949 | 954 | 959 | 963 | 968 | 973 | 978 | 983 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 891 | 988   | 993 | 998 | 002 | 007 | 012 | 017 | 022 | 027 | 032 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 892 | 95036 | 041 | 046 | 051 | 056 | 061 | 066 | 071 | 075 | 080 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 893 | 085   | 090 | 095 | 100 | 105 | 109 | 114 | 119 | 124 | 129 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 894 | 134   | 139 | 143 | 148 | 153 | 158 | 163 | 168 | 173 | 177 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 895 | 182   | 187 | 192 | 197 | 202 | 207 | 211 | 216 | 221 | 226 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 896 | 231   | 236 | 240 | 245 | 250 | 255 | 260 | 265 | 270 | 274 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 897 | 279   | 284 | 289 | 294 | 299 | 303 | 308 | 313 | 318 | 323 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 898 | 328   | 332 | 337 | 342 | 347 | 352 | 357 | 361 | 366 | 371 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 899 | 376   | 381 | 386 | 390 | 395 | 400 | 405 | 410 | 415 | 419 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |



900] Five-figure Logarithms—*continued.* [95

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 900 | 95424 | 429 | 434 | 439 | 444 | 448 | 453 | 458 | 463 | 468 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 901 | 472   | 477 | 482 | 487 | 492 | 497 | 501 | 506 | 511 | 516 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 902 | 521   | 525 | 530 | 535 | 540 | 545 | 550 | 554 | 559 | 564 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 903 | 569   | 574 | 578 | 583 | 588 | 593 | 598 | 602 | 607 | 612 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 904 | 617   | 622 | 626 | 631 | 636 | 641 | 646 | 650 | 655 | 660 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 905 | 665   | 670 | 674 | 679 | 684 | 689 | 694 | 698 | 703 | 708 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 906 | 713   | 718 | 722 | 727 | 732 | 737 | 742 | 746 | 751 | 756 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 907 | 761   | 766 | 770 | 775 | 780 | 785 | 789 | 794 | 799 | 804 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 908 | 809   | 813 | 818 | 823 | 828 | 832 | 837 | 842 | 847 | 852 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 909 | 856   | 861 | 866 | 871 | 875 | 880 | 885 | 890 | 895 | 899 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 910 | 904   | 909 | 914 | 918 | 923 | 928 | 933 | 938 | 942 | 947 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 911 | 952   | 957 | 961 | 966 | 971 | 976 | 980 | 985 | 990 | 995 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 912 | 999   | 004 | 009 | 014 | 019 | 023 | 028 | 033 | 038 | 042 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 913 | 96047 | 052 | 057 | 061 | 066 | 071 | 076 | 080 | 085 | 090 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 914 | 095   | 099 | 104 | 109 | 114 | 118 | 123 | 128 | 133 | 137 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 915 | 142   | 147 | 152 | 156 | 161 | 166 | 171 | 175 | 180 | 185 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 916 | 190   | 194 | 199 | 204 | 209 | 213 | 218 | 223 | 227 | 232 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 917 | 237   | 242 | 246 | 251 | 256 | 261 | 265 | 270 | 275 | 280 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 918 | 284   | 289 | 294 | 298 | 303 | 308 | 313 | 317 | 322 | 327 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 919 | 332   | 336 | 341 | 346 | 350 | 355 | 360 | 365 | 369 | 374 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 920 | 379   | 384 | 388 | 393 | 398 | 402 | 407 | 412 | 417 | 421 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 921 | 426   | 431 | 435 | 440 | 445 | 450 | 454 | 459 | 464 | 468 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 922 | 473   | 478 | 483 | 487 | 492 | 497 | 501 | 506 | 511 | 515 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 923 | 520   | 525 | 530 | 534 | 539 | 544 | 548 | 553 | 558 | 562 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 924 | 567   | 572 | 577 | 581 | 586 | 591 | 595 | 600 | 605 | 609 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 925 | 614   | 619 | 624 | 628 | 633 | 638 | 642 | 647 | 652 | 656 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 926 | 661   | 666 | 670 | 675 | 680 | 685 | 689 | 694 | 699 | 703 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 927 | 708   | 713 | 717 | 722 | 727 | 731 | 736 | 741 | 745 | 750 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 928 | 755   | 759 | 764 | 769 | 774 | 778 | 783 | 788 | 792 | 797 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 929 | 802   | 806 | 811 | 816 | 820 | 825 | 830 | 834 | 839 | 844 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 930 | 848   | 853 | 858 | 862 | 867 | 872 | 876 | 881 | 886 | 890 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 931 | 895   | 900 | 904 | 909 | 914 | 918 | 923 | 928 | 932 | 937 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 932 | 942   | 946 | 951 | 956 | 960 | 965 | 970 | 974 | 979 | 984 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 933 | 988   | 993 | 997 | 002 | 007 | 011 | 016 | 021 | 025 | 030 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 934 | 97035 | 039 | 044 | 049 | 053 | 058 | 063 | 067 | 072 | 077 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 935 | 081   | 086 | 090 | 095 | 100 | 104 | 109 | 114 | 118 | 123 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 936 | 128   | 132 | 137 | 142 | 146 | 151 | 155 | 160 | 165 | 169 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 937 | 174   | 179 | 183 | 188 | 192 | 197 | 202 | 206 | 211 | 216 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 938 | 220   | 225 | 230 | 234 | 239 | 243 | 248 | 253 | 257 | 262 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 939 | 267   | 271 | 276 | 280 | 285 | 290 | 294 | 299 | 304 | 308 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |

940] Five-figure Logarithms — *continued.*

[.97

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 940 | 97313 | 317 | 322 | 327 | 331 | 336 | 340 | 345 | 350 | 354 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 941 | 359   | 364 | 368 | 373 | 377 | 382 | 387 | 391 | 396 | 400 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 942 | 405   | 410 | 414 | 419 | 424 | 428 | 433 | 437 | 442 | 447 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 943 | 451   | 456 | 460 | 465 | 470 | 474 | 479 | 483 | 488 | 493 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 944 | 497   | 502 | 506 | 511 | 516 | 520 | 525 | 529 | 534 | 539 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 945 | 543   | 548 | 552 | 557 | 562 | 566 | 571 | 575 | 580 | 585 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 946 | 589   | 594 | 598 | 603 | 607 | 612 | 617 | 621 | 626 | 630 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 947 | 635   | 640 | 644 | 649 | 653 | 658 | 663 | 667 | 672 | 676 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 948 | 681   | 685 | 690 | 695 | 699 | 704 | 708 | 713 | 717 | 722 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 949 | 727   | 731 | 736 | 740 | 745 | 750 | 754 | 759 | 763 | 768 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 950 | 772   | 777 | 782 | 786 | 791 | 795 | 800 | 804 | 809 | 813 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 951 | 818   | 823 | 827 | 832 | 836 | 841 | 845 | 850 | 855 | 859 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 952 | 864   | 868 | 873 | 877 | 882 | 886 | 891 | 896 | 900 | 905 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 953 | 909   | 914 | 918 | 923 | 928 | 932 | 937 | 941 | 946 | 950 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 954 | 955   | 959 | 964 | 968 | 973 | 978 | 982 | 987 | 991 | 996 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 955 | 98000 | 005 | 009 | 014 | 019 | 023 | 028 | 032 | 037 | 041 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 956 | 046   | 050 | 055 | 059 | 064 | 068 | 073 | 078 | 082 | 087 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 957 | 091   | 096 | 100 | 105 | 109 | 114 | 118 | 123 | 127 | 132 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 958 | 137   | 141 | 146 | 150 | 155 | 159 | 164 | 168 | 173 | 177 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 959 | 182   | 186 | 191 | 195 | 200 | 204 | 209 | 214 | 218 | 223 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 960 | 227   | 232 | 236 | 241 | 245 | 250 | 254 | 259 | 263 | 268 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 961 | 272   | 277 | 281 | 286 | 290 | 295 | 299 | 304 | 308 | 313 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 962 | 318   | 322 | 327 | 331 | 336 | 340 | 345 | 349 | 354 | 358 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 963 | 363   | 367 | 372 | 376 | 381 | 385 | 390 | 394 | 399 | 403 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 964 | 408   | 412 | 417 | 421 | 426 | 430 | 435 | 439 | 444 | 448 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 965 | 453   | 457 | 462 | 466 | 471 | 475 | 480 | 484 | 489 | 493 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 966 | 498   | 502 | 507 | 511 | 516 | 520 | 525 | 529 | 534 | 538 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 967 | 543   | 547 | 552 | 556 | 561 | 565 | 570 | 574 | 579 | 583 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 968 | 588   | 592 | 597 | 601 | 605 | 610 | 614 | 619 | 623 | 628 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 969 | 632   | 637 | 641 | 646 | 650 | 655 | 659 | 664 | 668 | 673 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 970 | 677   | 682 | 686 | 691 | 695 | 700 | 704 | 709 | 713 | 717 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 971 | 722   | 726 | 731 | 735 | 740 | 744 | 749 | 753 | 758 | 762 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 972 | 767   | 771 | 776 | 780 | 784 | 789 | 793 | 798 | 802 | 807 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 973 | 811   | 816 | 820 | 825 | 829 | 834 | 838 | 843 | 847 | 851 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 974 | 856   | 860 | 865 | 869 | 874 | 878 | 883 | 887 | 892 | 896 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 975 | 900   | 905 | 909 | 914 | 918 | 923 | 927 | 932 | 936 | 941 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 976 | 945   | 949 | 954 | 958 | 963 | 967 | 972 | 976 | 981 | 985 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 977 | 989   | 994 | 998 | 003 | 007 | 012 | 016 | 021 | 025 | 029 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 978 | 99034 | 038 | 043 | 047 | 052 | 056 | 061 | 065 | 069 | 074 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 979 | 078   | 083 | 087 | 092 | 096 | 100 | 105 | 109 | 114 | 118 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |

# 080] Five-figure Logarithms—*continued.* [·99

|     | 0     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|---|---|---|---|---|
| 980 | 99123 | 127 | 131 | 136 | 140 | 145 | 149 | 154 | 158 | 162 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 981 | 167   | 171 | 176 | 180 | 185 | 189 | 193 | 198 | 202 | 207 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 982 | 211   | 216 | 220 | 224 | 229 | 233 | 238 | 242 | 247 | 251 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 983 | 255   | 260 | 264 | 269 | 273 | 277 | 282 | 286 | 291 | 295 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 984 | 300   | 304 | 308 | 313 | 317 | 322 | 326 | 330 | 335 | 339 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 985 | 344   | 348 | 352 | 357 | 361 | 366 | 370 | 374 | 379 | 383 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 986 | 388   | 392 | 396 | 401 | 405 | 410 | 414 | 419 | 423 | 427 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 987 | 432   | 436 | 441 | 445 | 449 | 454 | 458 | 463 | 467 | 471 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 988 | 476   | 480 | 484 | 489 | 493 | 498 | 502 | 506 | 511 | 515 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 989 | 520   | 524 | 528 | 533 | 537 | 542 | 546 | 550 | 555 | 559 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 990 | 564   | 568 | 572 | 577 | 581 | 585 | 590 | 594 | 599 | 603 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 991 | 607   | 612 | 616 | 621 | 625 | 629 | 634 | 638 | 642 | 647 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 992 | 651   | 656 | 660 | 664 | 669 | 673 | 677 | 682 | 686 | 691 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 993 | 695   | 699 | 704 | 708 | 712 | 717 | 721 | 726 | 730 | 734 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |
| 994 | 739   | 743 | 747 | 752 | 756 | 760 | 765 | 769 | 774 | 778 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |
| 995 | 782   | 787 | 791 | 795 | 800 | 804 | 808 | 813 | 817 | 822 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |
| 996 | 826   | 830 | 835 | 839 | 843 | 848 | 852 | 856 | 861 | 865 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |
| 997 | 870   | 874 | 878 | 883 | 887 | 891 | 896 | 900 | 904 | 909 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |
| 998 | 913   | 917 | 922 | 926 | 930 | 935 | 939 | 944 | 948 | 952 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |
| 999 | 957   | 961 | 965 | 970 | 974 | 978 | 983 | 987 | 991 | 996 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |

## Mathematical Constants and their Logarithms.

|   | Log.    |
|---|---------|
| $\pi = 3.14159265 \dots$ ( $= 22/7$ for all practical purposes) | 0.49715 |
| $180/\pi = 57.296^\circ$ = radian in degrees                    | 1.75813 |
| $e = 2.71828$   | 0.43429 |

To convert common to Napierian logarithms, multiply by  
 $\text{Log}_e 10 = 2.302585$ , or exponential  $(2.302585) = 10$ .

## Powers of Numbers, Areas, &amp;c.

| $n$ | $n^2$ | $n^3$  | $\sqrt{n}$ | $\frac{1}{n}$ | $\pi n$ | $\frac{\pi n^2}{4}$ |
|-----|-------|--------|------------|---------------|---------|---------------------|
| 1   | 1     | 1      | 1.0000     | 1.000000      | 3.142   | 0.7854              |
| 2   | 4     | 8      | 1.4142     | 0.500000      | 6.283   | 3.1416              |
| 3   | 9     | 27     | 1.7320     | 0.333333      | 9.425   | 7.0686              |
| 4   | 16    | 64     | 2.0000     | 0.250000      | 12.566  | 12.566              |
| 5   | 25    | 125    | 2.2361     | 0.200000      | 15.708  | 19.635              |
| 6   | 36    | 216    | 2.4495     | 0.166667      | 18.850  | 28.274              |
| 7   | 49    | 343    | 2.6458     | 0.142857      | 21.991  | 38.486              |
| 8   | 64    | 512    | 2.8284     | 0.125000      | 25.133  | 50.265              |
| 9   | 81    | 729    | 3.0000     | 0.111111      | 28.274  | 63.617              |
| 10  | 100   | 1000   | 3.1623     | 0.100000      | 31.416  | 78.540              |
| 11  | 121   | 1331   | 3.3166     | 0.090909      | 34.558  | 95.033              |
| 12  | 144   | 1728   | 3.4641     | 0.083333      | 37.699  | 113.10              |
| 13  | 169   | 2197   | 3.6056     | 0.076923      | 40.841  | 132.73              |
| 14  | 196   | 2744   | 3.7417     | 0.071429      | 43.982  | 153.94              |
| 15  | 225   | 3375   | 3.8730     | 0.066667      | 47.124  | 176.72              |
| 16  | 256   | 4096   | 4.0000     | 0.062500      | 50.265  | 201.06              |
| 17  | 289   | 4913   | 4.1231     | 0.058824      | 53.407  | 226.98              |
| 18  | 324   | 5832   | 4.2426     | 0.055556      | 56.549  | 254.47              |
| 19  | 361   | 6859   | 4.3589     | 0.052632      | 59.690  | 283.53              |
| 20  | 400   | 8000   | 4.4721     | 0.050000      | 62.832  | 314.16              |
| 21  | 441   | 9261   | 4.5826     | 0.047619      | 65.973  | 346.36              |
| 22  | 484   | 10648  | 4.6904     | 0.045455      | 69.115  | 380.13              |
| 23  | 529   | 12167  | 4.7958     | 0.043478      | 72.257  | 415.48              |
| 24  | 576   | 13824  | 4.8990     | 0.041667      | 75.398  | 452.39              |
| 25  | 625   | 15625  | 5.0000     | 0.040000      | 78.540  | 490.88              |
| 26  | 676   | 17576  | 5.0990     | 0.038462      | 81.681  | 530.93              |
| 27  | 729   | 19683  | 5.1962     | 0.037037      | 84.823  | 572.56              |
| 28  | 784   | 21952  | 5.2915     | 0.035714      | 87.965  | 615.75              |
| 29  | 841   | 24389  | 5.3852     | 0.034483      | 91.106  | 660.52              |
| 30  | 900   | 27000  | 5.4772     | 0.033333      | 94.248  | 706.86              |
| 31  | 961   | 29791  | 5.5678     | 0.032258      | 97.389  | 754.77              |
| 32  | 1024  | 32768  | 5.6568     | 0.031250      | 100.53  | 804.25              |
| 33  | 1089  | 35937  | 5.7446     | 0.030303      | 103.67  | 855.30              |
| 34  | 1156  | 39304  | 5.8310     | 0.029412      | 106.81  | 907.92              |
| 35  | 1225  | 42875  | 5.9161     | 0.028571      | 109.96  | 962.12              |
| 36  | 1296  | 46656  | 6.0000     | 0.027778      | 113.10  | 1017.88             |
| 37  | 1369  | 50653  | 6.0828     | 0.027027      | 116.24  | 1075.21             |
| 38  | 1444  | 54872  | 6.1644     | 0.026316      | 119.38  | 1134.11             |
| 39  | 1521  | 59319  | 6.2450     | 0.025641      | 122.52  | 1194.59             |
| 40  | 1600  | 64000  | 6.3246     | 0.025000      | 125.66  | 1256.64             |
| 41  | 1681  | 68921  | 6.4031     | 0.024390      | 128.81  | 1320.25             |
| 42  | 1764  | 74088  | 6.4807     | 0.023810      | 131.95  | 1385.44             |
| 43  | 1849  | 79507  | 6.5574     | 0.023256      | 135.09  | 1452.20             |
| 44  | 1936  | 85184  | 6.6332     | 0.022727      | 138.23  | 1520.53             |
| 45  | 2025  | 91125  | 6.7082     | 0.022222      | 141.37  | 1590.43             |
| 46  | 2116  | 97336  | 6.7823     | 0.021739      | 144.51  | 1661.90             |
| 47  | 2209  | 103823 | 6.8556     | 0.021277      | 147.65  | 1734.94             |
| 48  | 2304  | 110592 | 6.9282     | 0.020833      | 150.80  | 1809.56             |
| 49  | 2401  | 117649 | 7.0000     | 0.020408      | 153.94  | 1885.74             |

| $n$ | $n^2$ | $n^3$   | $\sqrt{n}$ | $\frac{1}{n}$ | $\pi n$ | $\frac{\pi n^2}{4}$ |
|-----|-------|---------|------------|---------------|---------|---------------------|
| 50  | 2500  | 125000  | 7.0711     | 0.020000      | 157.08  | 1963.50             |
| 51  | 2601  | 132651  | 7.1414     | 0.019608      | 160.22  | 2042.82             |
| 52  | 2704  | 140608  | 7.2111     | 0.019231      | 163.36  | 2123.72             |
| 53  | 2809  | 148877  | 7.2801     | 0.018868      | 166.50  | 2206.19             |
| 54  | 2916  | 157464  | 7.3485     | 0.018519      | 169.64  | 2290.22             |
| 55  | 3025  | 166375  | 7.4162     | 0.018182      | 172.78  | 2375.83             |
| 56  | 3136  | 175616  | 7.4833     | 0.017857      | 175.93  | 2463.01             |
| 57  | 3249  | 185193  | 7.5498     | 0.017544      | 179.07  | 2551.76             |
| 58  | 3364  | 195112  | 7.6158     | 0.017241      | 182.21  | 2642.08             |
| 59  | 3481  | 205379  | 7.6812     | 0.016949      | 185.35  | 2733.97             |
| 60  | 3600  | 216000  | 7.7460     | 0.016667      | 188.49  | 2827.44             |
| 61  | 3721  | 226981  | 7.8102     | 0.016393      | 191.63  | 2922.47             |
| 62  | 3844  | 238328  | 7.8740     | 0.016129      | 194.77  | 3019.07             |
| 63  | 3969  | 250047  | 7.9372     | 0.015873      | 197.92  | 3117.25             |
| 64  | 4096  | 262144  | 8.0000     | 0.015625      | 201.06  | 3216.99             |
| 65  | 4225  | 274625  | 8.0623     | 0.015385      | 204.20  | 3318.31             |
| 66  | 4356  | 287496  | 8.1240     | 0.015152      | 207.34  | 3421.20             |
| 67  | 4489  | 300763  | 8.1854     | 0.014925      | 210.48  | 3525.66             |
| 68  | 4624  | 314432  | 8.2462     | 0.014706      | 213.63  | 3631.69             |
| 69  | 4761  | 328509  | 8.3066     | 0.014493      | 216.77  | 3739.29             |
| 70  | 4900  | 343000  | 8.3666     | 0.014286      | 219.91  | 3848.46             |
| 71  | 5041  | 357911  | 8.4262     | 0.014085      | 223.05  | 3959.20             |
| 72  | 5184  | 373248  | 8.4853     | 0.013889      | 226.19  | 4071.51             |
| 73  | 5329  | 389017  | 8.5440     | 0.013699      | 229.33  | 4185.39             |
| 74  | 5476  | 405224  | 8.6023     | 0.013514      | 232.47  | 4300.85             |
| 75  | 5625  | 421875  | 8.6602     | 0.013333      | 235.62  | 4417.87             |
| 76  | 5776  | 438976  | 8.7178     | 0.013158      | 238.76  | 4536.47             |
| 77  | 5929  | 456533  | 8.7750     | 0.012987      | 241.90  | 4656.63             |
| 78  | 6084  | 474552  | 8.8318     | 0.012821      | 245.04  | 4778.37             |
| 79  | 6241  | 493039  | 8.8882     | 0.012658      | 248.18  | 4901.68             |
| 80  | 6400  | 512000  | 8.9443     | 0.012500      | 251.32  | 5026.56             |
| 81  | 6561  | 531441  | 9.0000     | 0.012346      | 254.47  | 5153.01             |
| 82  | 6724  | 551368  | 9.0554     | 0.012195      | 257.61  | 5281.03             |
| 83  | 6889  | 571787  | 9.1104     | 0.012048      | 260.75  | 5410.62             |
| 84  | 7056  | 592704  | 9.1652     | 0.011905      | 263.89  | 5541.78             |
| 85  | 7225  | 614125  | 9.2195     | 0.011765      | 267.03  | 5674.50             |
| 86  | 7396  | 636056  | 9.2736     | 0.011628      | 270.17  | 5808.81             |
| 87  | 7569  | 658503  | 9.3274     | 0.011494      | 273.32  | 5944.69             |
| 88  | 7744  | 681472  | 9.3808     | 0.011364      | 276.46  | 6082.13             |
| 89  | 7921  | 704969  | 9.4340     | 0.011236      | 279.60  | 6221.13             |
| 90  | 8100  | 729000  | 9.4868     | 0.011111      | 282.74  | 6361.74             |
| 91  | 8281  | 753571  | 9.5394     | 0.010989      | 285.88  | 6503.89             |
| 92  | 8464  | 778688  | 9.5917     | 0.010870      | 289.02  | 6647.62             |
| 93  | 8649  | 804357  | 9.6436     | 0.010753      | 292.17  | 6792.92             |
| 94  | 8836  | 830584  | 9.6954     | 0.010638      | 295.31  | 6939.78             |
| 95  | 9025  | 857375  | 9.7468     | 0.010526      | 298.45  | 7088.23             |
| 96  | 9216  | 884736  | 9.7980     | 0.010417      | 301.59  | 7238.24             |
| 97  | 9409  | 912673  | 9.8489     | 0.010309      | 304.73  | 7389.83             |
| 98  | 9604  | 941192  | 9.8995     | 0.010204      | 307.87  | 7542.98             |
| 99  | 9801  | 970299  | 9.9499     | 0.010101      | 311.02  | 7697.68             |
| 100 | 10000 | 1000000 | 10.0000    | 0.010000      | 314.16  | 7854.00             |

Approx. Formulæ:  $\sqrt{a^2 \pm b} = a \pm \frac{b}{2a}$  and  $\sqrt[3]{a^3 \pm b} = a \pm \frac{b}{3a^2}$

## Natural Sines.

## Natural Tangents.

|    | 0'    | 10'   | 20'   | 30'   | 40'   | 50'   | 0'    | 10'   | 20'   | 30'   | 40'   | 50'   |
|----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0° | ·0000 | ·0029 | ·0058 | ·0087 | ·0116 | ·0145 | ·0000 | ·0029 | ·0058 | ·0087 | ·0116 | ·0145 |
| 1  | ·0175 | ·0204 | ·0233 | ·0262 | ·0291 | ·0320 | ·0175 | ·0204 | ·0233 | ·0262 | ·0291 | ·0320 |
| 2  | ·0349 | ·0378 | ·0407 | ·0436 | ·0465 | ·0494 | ·0349 | ·0378 | ·0407 | ·0437 | ·0466 | ·0495 |
| 3  | ·0523 | ·0552 | ·0581 | ·0610 | ·0640 | ·0669 | ·0524 | ·0553 | ·0582 | ·0612 | ·0641 | ·0670 |
| 4  | ·0698 | ·0727 | ·0756 | ·0785 | ·0814 | ·0843 | ·0699 | ·0729 | ·0758 | ·0787 | ·0816 | ·0845 |
| 5  | ·0872 | ·0901 | ·0929 | ·0958 | ·0987 | ·1016 | ·0875 | ·0904 | ·0934 | ·0963 | ·0992 | ·1021 |
| 6  | ·1045 | ·1074 | ·1103 | ·1132 | ·1161 | ·1190 | ·1051 | ·1080 | ·1110 | ·1139 | ·1169 | ·1198 |
| 7  | ·1219 | ·1248 | ·1276 | ·1305 | ·1334 | ·1363 | ·1228 | ·1257 | ·1287 | ·1317 | ·1346 | ·1375 |
| 8  | ·1392 | ·1421 | ·1449 | ·1478 | ·1507 | ·1536 | ·1405 | ·1435 | ·1465 | ·1495 | ·1524 | ·1553 |
| 9  | ·1564 | ·1593 | ·1622 | ·1650 | ·1679 | ·1708 | ·1584 | ·1614 | ·1644 | ·1673 | ·1703 | ·1732 |
| 10 | ·1736 | ·1765 | ·1794 | ·1822 | ·1851 | ·1880 | ·1763 | ·1793 | ·1823 | ·1853 | ·1883 | ·1911 |
| 11 | ·1908 | ·1937 | ·1965 | ·1994 | ·2022 | ·2051 | ·1944 | ·1974 | ·2004 | ·2035 | ·2065 | ·2095 |
| 12 | ·2079 | ·2108 | ·2136 | ·2164 | ·2193 | ·2221 | ·2126 | ·2156 | ·2186 | ·2217 | ·2247 | ·2276 |
| 13 | ·2250 | ·2278 | ·2306 | ·2334 | ·2363 | ·2391 | ·2309 | ·2339 | ·2370 | ·2401 | ·2432 | ·2461 |
| 14 | ·2419 | ·2447 | ·2476 | ·2504 | ·2532 | ·2560 | ·2493 | ·2524 | ·2555 | ·2586 | ·2617 | ·2646 |
| 15 | ·2588 | ·2616 | ·2644 | ·2672 | ·2700 | ·2728 | ·2679 | ·2711 | ·2742 | ·2773 | ·2805 | ·2836 |
| 16 | ·2756 | ·2784 | ·2812 | ·2840 | ·2868 | ·2896 | ·2867 | ·2899 | ·2931 | ·2962 | ·2994 | ·3025 |
| 17 | ·2924 | ·2952 | ·2979 | ·3007 | ·3035 | ·3062 | ·3057 | ·3089 | ·3121 | ·3153 | ·3185 | ·3216 |
| 18 | ·3090 | ·3118 | ·3145 | ·3173 | ·3201 | ·3228 | ·3249 | ·3281 | ·3314 | ·3346 | ·3378 | ·3409 |
| 19 | ·3256 | ·3283 | ·3311 | ·3338 | ·3365 | ·3393 | ·3443 | ·3476 | ·3508 | ·3541 | ·3574 | ·3606 |
| 20 | ·3420 | ·3448 | ·3475 | ·3502 | ·3529 | ·3557 | ·3640 | ·3673 | ·3706 | ·3739 | ·3772 | ·3805 |
| 21 | ·3584 | ·3611 | ·3638 | ·3665 | ·3692 | ·3719 | ·3839 | ·3872 | ·3906 | ·3939 | ·3973 | ·4006 |
| 22 | ·3746 | ·3773 | ·3800 | ·3827 | ·3854 | ·3881 | ·4040 | ·4074 | ·4108 | ·4142 | ·4176 | ·4209 |
| 23 | ·3907 | ·3934 | ·3961 | ·3987 | ·4014 | ·4041 | ·4245 | ·4279 | ·4314 | ·4348 | ·4383 | ·4416 |
| 24 | ·4067 | ·4094 | ·4120 | ·4147 | ·4173 | ·4200 | ·4452 | ·4487 | ·4522 | ·4557 | ·4592 | ·4626 |
| 25 | ·4226 | ·4253 | ·4279 | ·4305 | ·4331 | ·4358 | ·4663 | ·4699 | ·4734 | ·4770 | ·4806 | ·4841 |
| 26 | ·4384 | ·4410 | ·4436 | ·4462 | ·4488 | ·4514 | ·4877 | ·4913 | ·4950 | ·4986 | ·5022 | ·5058 |
| 27 | ·4540 | ·4566 | ·4592 | ·4617 | ·4643 | ·4669 | ·5095 | ·5132 | ·5169 | ·5206 | ·5243 | ·5280 |
| 28 | ·4695 | ·4720 | ·4746 | ·4772 | ·4797 | ·4823 | ·5317 | ·5354 | ·5392 | ·5430 | ·5467 | ·5504 |
| 29 | ·4848 | ·4874 | ·4899 | ·4924 | ·4950 | ·4975 | ·5543 | ·5581 | ·5619 | ·5658 | ·5696 | ·5734 |
| 30 | ·5000 | ·5025 | ·5050 | ·5075 | ·5100 | ·5125 | ·5774 | ·5812 | ·5851 | ·5890 | ·5930 | ·5969 |
| 31 | ·5150 | ·5175 | ·5200 | ·5225 | ·5250 | ·5275 | ·6009 | ·6048 | ·6088 | ·6128 | ·6168 | ·6208 |
| 32 | ·5299 | ·5324 | ·5348 | ·5373 | ·5398 | ·5422 | ·6249 | ·6289 | ·6330 | ·6371 | ·6412 | ·6452 |
| 33 | ·5446 | ·5471 | ·5495 | ·5519 | ·5544 | ·5568 | ·6494 | ·6536 | ·6577 | ·6619 | ·6661 | ·6702 |
| 34 | ·5592 | ·5616 | ·5640 | ·5664 | ·5688 | ·5712 | ·6745 | ·6787 | ·6830 | ·6873 | ·6916 | ·6959 |
| 35 | ·5736 | ·5760 | ·5783 | ·5807 | ·5831 | ·5854 | ·7002 | ·7046 | ·7089 | ·7133 | ·7177 | ·7220 |
| 36 | ·5878 | ·5901 | ·5925 | ·5948 | ·5972 | ·5995 | ·7265 | ·7310 | ·7355 | ·7400 | ·7445 | ·7489 |
| 37 | ·6018 | ·6041 | ·6065 | ·6088 | ·6111 | ·6134 | ·7536 | ·7581 | ·7627 | ·7673 | ·7720 | ·7765 |
| 38 | ·6157 | ·6180 | ·6202 | ·6225 | ·6248 | ·6271 | ·7813 | ·7860 | ·7907 | ·7954 | ·8002 | ·8049 |
| 39 | ·6293 | ·6316 | ·6338 | ·6361 | ·6383 | ·6406 | ·8098 | ·8146 | ·8195 | ·8243 | ·8292 | ·8340 |
| 40 | ·6428 | ·6450 | ·6472 | ·6494 | ·6517 | ·6539 | ·8391 | ·8441 | ·8491 | ·8541 | ·8591 | ·8640 |
| 41 | ·6561 | ·6583 | ·6604 | ·6626 | ·6648 | ·6670 | ·8693 | ·8744 | ·8796 | ·8847 | ·8899 | ·8950 |
| 42 | ·6691 | ·6713 | ·6734 | ·6756 | ·6777 | ·6799 | ·9004 | ·9057 | ·9110 | ·9163 | ·9217 | ·9270 |
| 43 | ·6820 | ·6841 | ·6862 | ·6884 | ·6905 | ·6926 | ·9325 | ·9380 | ·9435 | ·9490 | ·9545 | ·9600 |
| 44 | ·6947 | ·6967 | ·6988 | ·7009 | ·7030 | ·7050 | ·9657 | ·9713 | ·9770 | ·9827 | ·9884 | ·9940 |



## Natural Sines.

## Natural Tangents.

|     | 0'    | 10'   | 20'   | 30'   | 40'   | 50'   |       | 0'    | 10'   | 20'   | 30'   | 40'   | 50'   |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 45° | ·7071 | ·7092 | ·7112 | ·7133 | ·7153 | ·7173 | 1·000 | 1·006 | 1·012 | 1·018 | 1·023 | 1·029 | 1·036 |
| 46  | ·7193 | ·7214 | ·7234 | ·7254 | ·7274 | ·7294 | 1·036 | 1·042 | 1·048 | 1·054 | 1·060 | 1·066 | 1·072 |
| 47  | ·7314 | ·7333 | ·7353 | ·7373 | ·7392 | ·7412 | 1·072 | 1·079 | 1·085 | 1·091 | 1·098 | 1·104 | 1·111 |
| 48  | ·7431 | ·7451 | ·7470 | ·7490 | ·7509 | ·7528 | 1·111 | 1·117 | 1·124 | 1·130 | 1·137 | 1·144 | 1·150 |
| 49  | ·7547 | ·7566 | ·7585 | ·7604 | ·7623 | ·7642 | 1·150 | 1·157 | 1·164 | 1·171 | 1·178 | 1·185 | 1·192 |
| 50  | ·7660 | ·7679 | ·7698 | ·7716 | ·7735 | ·7753 | 1·192 | 1·199 | 1·206 | 1·213 | 1·220 | 1·228 | 1·235 |
| 51  | ·7771 | ·7790 | ·7808 | ·7826 | ·7844 | ·7862 | 1·235 | 1·242 | 1·250 | 1·257 | 1·265 | 1·272 | 1·280 |
| 52  | ·7880 | ·7898 | ·7916 | ·7934 | ·7951 | ·7969 | 1·280 | 1·288 | 1·295 | 1·303 | 1·311 | 1·319 | 1·327 |
| 53  | ·7986 | ·8004 | ·8021 | ·8039 | ·8056 | ·8073 | 1·327 | 1·335 | 1·343 | 1·351 | 1·360 | 1·368 | 1·376 |
| 54  | ·8090 | ·8107 | ·8124 | ·8141 | ·8158 | ·8175 | 1·376 | 1·385 | 1·393 | 1·402 | 1·411 | 1·419 | 1·428 |
| 55  | ·8192 | ·8208 | ·8225 | ·8241 | ·8258 | ·8274 | 1·428 | 1·437 | 1·446 | 1·455 | 1·464 | 1·473 | 1·483 |
| 56  | ·8290 | ·8307 | ·8323 | ·8339 | ·8355 | ·8371 | 1·483 | 1·492 | 1·501 | 1·511 | 1·520 | 1·530 | 1·540 |
| 57  | ·8387 | ·8403 | ·8418 | ·8434 | ·8450 | ·8465 | 1·540 | 1·550 | 1·560 | 1·570 | 1·580 | 1·590 | 1·600 |
| 58  | ·8480 | ·8496 | ·8511 | ·8526 | ·8542 | ·8557 | 1·600 | 1·611 | 1·621 | 1·632 | 1·643 | 1·653 | 1·664 |
| 59  | ·8572 | ·8587 | ·8601 | ·8616 | ·8631 | ·8646 | 1·664 | 1·675 | 1·686 | 1·698 | 1·709 | 1·720 | 1·732 |
| 60  | ·8660 | ·8675 | ·8689 | ·8704 | ·8718 | ·8732 | 1·732 | 1·744 | 1·756 | 1·768 | 1·780 | 1·792 | 1·804 |
| 61  | ·8746 | ·8760 | ·8774 | ·8788 | ·8802 | ·8816 | 1·804 | 1·816 | 1·829 | 1·842 | 1·855 | 1·868 | 1·881 |
| 62  | ·8829 | ·8843 | ·8857 | ·8870 | ·8884 | ·8897 | 1·881 | 1·894 | 1·907 | 1·921 | 1·935 | 1·949 | 1·963 |
| 63  | ·8910 | ·8923 | ·8936 | ·8949 | ·8962 | ·8975 | 1·963 | 1·977 | 1·991 | 2·006 | 2·020 | 2·035 | 2·050 |
| 64  | ·8988 | ·9001 | ·9013 | ·9026 | ·9038 | ·9051 | 2·050 | 2·065 | 2·081 | 2·096 | 2·112 | 2·128 | 2·144 |
| 65  | ·9063 | ·9075 | ·9088 | ·9100 | ·9112 | ·9124 | 2·144 | 2·161 | 2·178 | 2·194 | 2·211 | 2·229 | 2·246 |
| 66  | ·9135 | ·9147 | ·9159 | ·9171 | ·9182 | ·9194 | 2·246 | 2·264 | 2·282 | 2·300 | 2·318 | 2·337 | 2·356 |
| 67  | ·9205 | ·9216 | ·9228 | ·9239 | ·9250 | ·9261 | 2·356 | 2·375 | 2·394 | 2·414 | 2·434 | 2·454 | 2·475 |
| 68  | ·9272 | ·9283 | ·9293 | ·9304 | ·9315 | ·9325 | 2·475 | 2·496 | 2·517 | 2·539 | 2·560 | 2·583 | 2·605 |
| 69  | ·9336 | ·9346 | ·9356 | ·9367 | ·9377 | ·9387 | 2·605 | 2·628 | 2·651 | 2·675 | 2·699 | 2·723 | 2·747 |
| 70  | ·9397 | ·9407 | ·9417 | ·9426 | ·9436 | ·9446 | 2·747 | 2·773 | 2·798 | 2·824 | 2·850 | 2·877 | 2·904 |
| 71  | ·9455 | ·9465 | ·9474 | ·9483 | ·9492 | ·9502 | 2·904 | 2·932 | 2·960 | 2·989 | 3·018 | 3·047 | 3·078 |
| 72  | ·9511 | ·9520 | ·9528 | ·9537 | ·9546 | ·9555 | 3·078 | 3·108 | 3·140 | 3·172 | 3·204 | 3·237 | 3·271 |
| 73  | ·9563 | ·9572 | ·9580 | ·9588 | ·9596 | ·9605 | 3·271 | 3·305 | 3·340 | 3·376 | 3·412 | 3·450 | 3·487 |
| 74  | ·9613 | ·9621 | ·9628 | ·9636 | ·9644 | ·9652 | 3·487 | 3·526 | 3·566 | 3·606 | 3·647 | 3·689 | 3·732 |
| 75  | ·9659 | ·9667 | ·9674 | ·9681 | ·9689 | ·9696 | 3·732 | 3·776 | 3·821 | 3·867 | 3·914 | 3·962 | 4·011 |
| 76  | ·9703 | ·9710 | ·9717 | ·9724 | ·9730 | ·9737 | 4·011 | 4·061 | 4·113 | 4·165 | 4·219 | 4·275 | 4·331 |
| 77  | ·9744 | ·9750 | ·9757 | ·9763 | ·9769 | ·9775 | 4·331 | 4·390 | 4·449 | 4·511 | 4·574 | 4·638 | 4·705 |
| 78  | ·9781 | ·9787 | ·9793 | ·9799 | ·9805 | ·9811 | 4·705 | 4·773 | 4·843 | 4·915 | 4·989 | 5·066 | 5·145 |
| 79  | ·9816 | ·9822 | ·9827 | ·9833 | ·9838 | ·9843 | 5·145 | 5·226 | 5·309 | 5·396 | 5·485 | 5·076 | 5·671 |
| 80  | ·9848 | ·9853 | ·9858 | ·9863 | ·9868 | ·9872 | 5·671 | 5·769 | 5·871 | 5·976 | 6·084 | 6·197 | 6·314 |
| 81  | ·9877 | ·9881 | ·9886 | ·9890 | ·9894 | ·9899 | 6·314 | 6·435 | 6·561 | 6·691 | 6·827 | 6·968 | 7·115 |
| 82  | ·9903 | ·9907 | ·9911 | ·9914 | ·9918 | ·9922 | 7·115 | 7·269 | 7·429 | 7·596 | 7·770 | 7·953 | 8·144 |
| 83  | ·9925 | ·9929 | ·9932 | ·9936 | ·9939 | ·9942 | 8·144 | 8·345 | 8·556 | 8·777 | 9·010 | 9·255 | 9·514 |
| 84  | ·9945 | ·9948 | ·9951 | ·9954 | ·9957 | ·9959 | 9·514 | 9·788 | 10·08 | 10·39 | 10·71 | 11·06 | 11·43 |
| 85  | ·9962 | ·9964 | ·9967 | ·9969 | ·9971 | ·9974 | 11·43 | 11·83 | 12·25 | 12·71 | 13·20 | 13·73 | 14·30 |
| 86  | ·9976 | ·9978 | ·9980 | ·9981 | ·9983 | ·9985 | 14·30 | 14·92 | 15·60 | 16·35 | 17·17 | 18·07 | 19·08 |
| 87  | ·9986 | ·9988 | ·9989 | ·9990 | ·9992 | ·9993 | 19·08 | 20·21 | 21·47 | 22·90 | 24·54 | 26·43 | 28·64 |
| 88  | ·9994 | ·9995 | ·9996 | ·9997 | ·9997 | ·9998 | 28·64 | 31·24 | 34·37 | 38·19 | 42·96 | 49·10 | 57·29 |
| 89  | ·9998 | ·9999 | ·9999 |       |       |       | 57·29 | 68·75 | 85·94 | 114·6 | 171·9 | 343·8 |       |



## Mensuration Formulæ.

**Triangle.** Area =  $\frac{1}{2}$  (base  $\times$  height), or =  $\sqrt{s(s-a)(s-b)(s-c)}$ ,  
where  $s = \frac{1}{2}(a+b+c)$ .

**Parallelogram.** Area = base  $\times$  height.

**Simpson's rule.** Area =  $\frac{l}{3}(A + 4B + 2C)$ ,

where  $l$  = space between two consecutive ordinates

A = sum of first and last ordinates;

B = sum of the even ordinates;

and C = sum of the odd ordinates.

**Circle.** Circumference =  $2\pi r$ .

$$\text{Area} = \pi r^2 \text{ or } \frac{\pi d^2}{4}$$

**Annular ring.** Area =  $\pi(R^2 - r^2)$ .

**Ellipse.** Area =  $\frac{\pi}{4}$  (product of axes).

**Cylinder.** Surface =  $2\pi r h + 2\pi r^2$ .

$$\text{Volume} = \pi r^2 h.$$

**Prism.** Surface =  $2(ab + bc + ca)$ .

$$\text{Volume} = abc.$$

$$\text{Diagonal} = \sqrt{a^2 + b^2 + c^2}.$$

**Sphere.** Surface =  $4\pi r^2$ .

$$\text{Volume} = \frac{4}{3}\pi r^3.$$

**Cone.** Curved surface =  $4\pi r \times \text{slant height} = \pi r \sqrt{r^2 + h^2}$ .

$$\text{Volume} = \frac{\pi}{3} r^2 h.$$

**Frustum of cone.** Surface =  $\pi(R + r) \times \text{slant height}$ .

$$\text{Volume} = \frac{\pi h}{3} (R^2 + r^2 + Rr).$$

**Pyramid.** Volume =  $\frac{1}{3}$  (area of base  $\times h$ ).

## Trigonometrical Formulæ.

$$\sin a = \frac{\text{opposite}}{\text{hypotenuse}}; \quad \cos a = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\sin a = \sin(180^\circ - a) = \cos(90^\circ - a)$$

$$\cos(180^\circ - a) = -\cos a.$$

$$\tan a = \frac{\text{opposite}}{\text{adjacent}}$$

$$\text{In triangle ABC: } \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}.$$

$$\text{Area} = \frac{1}{2} bc \sin A$$

# Mechanical Constants and their Logarithms.

|   |         |
|---|---------|
| $g = 32.2$ ft. per sec. <sup>2</sup>  | Log.    |
| $= 981$ cm. per sec. <sup>2</sup>   | 1.50786 |
| (Actual figures : London, 32.19078; Paris, 32.18255; New York, 32.15945 ft. per sec. <sup>2</sup> ) | 2.99167 |

|                                  |   |         |
|----------------------------------|---|---------|
| 1 lb. weight                     | $= 4.45 \times 10^5$ dynes              | Log.    |
| 1 ft.-lb.                        | $= 1.356 \times 10^7$ ergs              | 5.64836 |
| $10^6$ dynes                     | $= 2.247$ lb. weight                    | 7.13226 |
| $10^8$ ergs                      | $= 7.371$ ft.-lb.                       | 0.35160 |
| 1 atmosphere                     | $= 14.7$ lb. weight per sq. in.         | 0.86753 |
|                                  | $= 1.014 \times 10^6$ dynes per sq. cm. | 1.16732 |
| 1 horse-power                    | $= 33000$ ft.-lb. per min.              | 6.00604 |
| Mechanical equivalent of heat, J | $= 426.9$ calories                      | 4.51851 |
| 1 B. Th. U.                      | $= 0.252$ Calorie (K)                   | 2.63033 |
|                                  | $= 252$ calories                        | 1.40140 |
|                                  | $= 778$ ft. lbs.                        | 2.40140 |
| 1 (large) Calorie                | $= 3.968$ B. Th. U.                     | 2.89098 |
| 1 H.P.                           | $= 0.707$ B. Th. U. per sec.            | 0.59857 |
|                                  | $= 0.178$ Calorie per sec.              | 1.84942 |
|                                  | $= 0.746$ Kilowatt.                     | 1.25042 |
| 1 Kilowatt                       | $= 0.949$ B. Th. U. per sec.            | 1.87274 |
|                                  | $= 0.239$ Calorie per sec.              | 1.97727 |
|                                  | $= 738$ ft.-lbs. per sec.               | 1.37840 |
|                                  | $= 1.341$ H.P.                          | 2.86806 |
|                                  |   | 0.12743 |

## Conversion of Pounds per sq. inch to Kilograms per sq. cm.

1 lb. per sq. in.  $= 0.070310$  kgm. per sq. cm.

|     | 0      | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      |
|-----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 0   |        | 0.0703 | 0.1406 | 0.2109 | 0.2812 | 0.3516 | 0.4219 | 0.4922 | 0.5625 | 0.6328 |
| 10  | 0.7031 | 0.7734 | 0.8437 | 0.9140 | 0.9843 | 1.0546 | 1.1250 | 1.1953 | 1.2656 | 1.3359 |
| 20  | 1.4062 | 1.4765 | 1.5468 | 1.6171 | 1.6874 | 1.7577 | 1.8280 | 1.8984 | 1.9687 | 2.0390 |
| 30  | 2.1093 | 2.1796 | 2.2499 | 2.3202 | 2.3905 | 2.4608 | 2.5311 | 2.6015 | 2.6718 | 2.7421 |
| 40  | 2.8124 | 2.8827 | 2.9530 | 3.0233 | 3.0936 | 3.1639 | 3.2342 | 3.3045 | 3.3749 | 3.4452 |
| 50  | 3.5155 | 3.5858 | 3.6561 | 3.7264 | 3.7967 | 3.8670 | 3.9373 | 4.0076 | 4.0780 | 4.1483 |
| 60  | 4.2186 | 4.2889 | 4.3592 | 4.4295 | 4.4998 | 4.5701 | 4.6404 | 4.7107 | 4.7810 | 4.8514 |
| 70  | 4.9217 | 4.9920 | 5.0623 | 5.1326 | 5.2029 | 5.2732 | 5.3435 | 5.4138 | 5.4841 | 5.5545 |
| 80  | 5.6248 | 5.6951 | 5.7654 | 5.8357 | 5.9060 | 5.9763 | 6.0466 | 6.1169 | 6.1872 | 6.2575 |
| 90  | 6.3279 | 6.3982 | 6.4685 | 6.5388 | 6.6091 | 6.6794 | 6.7497 | 6.8200 | 6.8903 | 6.9606 |
| 100 | 7.0310 | 7.1013 | 7.1716 | 7.2419 | 7.3122 | 7.3825 | 7.4528 | 7.5231 | 7.5934 | 7.6637 |

*MEMORANDA AND SUGGESTIONS.*

---

(In case you are unable to find the data you require,  
please write :

Dr. F. W. ATACK, 34, Cross Street, Manchester.)

---

# INDEX.

---

|   | Page     |
|---|----------|
| Acetic acid solutions, density of - . . . . .               | 37       |
| Acetyl value - . . . . .                                    | 724      |
| Acid radicals, confirmatory tests for . . . . .             | 537      |
| — — —, examination for . . . . .                            | 532      |
| — — —, separation of . . . . .                              | 546      |
| — value . . . . .   | 724      |
| Agricultural chemistry . . . . .                            | 798      |
| Air, density of dry . . . . .                               | 109      |
| —, — — —, half-saturated with water vapour . . . . .        | 111      |
| —, expansion, coefficient of . . . . .                      | 160      |
| —, solubility in water . . . . .                            | 117, 118 |
| Alcohol content of beer and spirits . . . . .               | 921      |
| —, conversion of sp. gr. to proof spirit . . . . .          | 928      |
| —, dilution of . . . . .                                    | 43, 932  |
| —-ether mixtures, specific gravity of . . . . .             | 48       |
| —, methyl, density of solutions of . . . . .                | 48       |
| — solutions, boiling points of . . . . .                    | 932      |
| — — —, change in density with temp. . . . .                 | 46       |
| — — —, composition of . . . . .                             | 41, 43   |
| — — —, density of . . . . .                                 | 38       |
| — — —, dilution of . . . . .                                | 43, 47   |
| — — —, specific gravity of . . . . .                        | 41, 928  |
| — — —, viscosities of . . . . .                             | 20       |
| Alkali, detection of free . . . . .                         | 532      |
| Alkalimetric degrees . . . . .                              | 711, 712 |
| Alkaloid reagents . . . . .                                 | 1049     |
| Alkaloids, characteristics of . . . . .                     | 1052     |
| —, colour reactions of . . . . .                            | 1051     |
| —, systematic tests for . . . . .                           | 1048     |
| Alloys, composition of . . . . .                            | 14, 34   |
| —, density of . . . . .                                     | 34       |
| —, examination of . . . . .                                 | 566      |
| — of low melting point, melting points of . . . . .         | 14       |
| — of precious metals, melting points of . . . . .           | 15       |
| —, physical constants of . . . . .                          | 14       |
| Aluminium chloride solutions, specific gravity of . . . . . | 49       |
| — sulphate solutions, specific gravity of . . . . .         | 49       |
| — — —, solubility of . . . . .                              | 124      |
| American and British units, relation of . . . . .           | 1127     |

|  | Page     |
|--|----------|
| Ammonia alum solutions, specific gravity of      | 49       |
| — —, solubility of                               | 124      |
| — chrome alum solutions, specific gravity of     | 50       |
| — iron alum solutions, specific gravity of       | 51       |
| — solutions, specific gravity of                 | 50, 717  |
| —, solubility in water                           | 118, 120 |
| Ammonium acetate solutions, specific gravity of  | 50       |
| — carbonate solutions, specific gravity of       | 52       |
| — chloride solutions, specific gravity of        | 52       |
| — —, solubility of                               | 125      |
| — nitrate solutions, specific gravity of         | 53       |
| — —, solubility of                               | 124      |
| — salts by hypobromite, determination of         | 621      |
| — sulphate solutions, specific gravity of        | 53       |
| — —, solubility of                               | 126      |
| — thiocyanate, standard                          | 594      |
| — —, solubility of                               | 127      |
| Aniline oils                                     | 975      |
| —, solubility of                                 | 157, 975 |
| Anthracene, examination of                       | 973      |
| — and anthraquinone, equivalent weights of       | 974      |
| Aqua regia                                       | 530      |
| Areas  | 1160     |
| Argol, valuation of                              | 587      |
| Arsenic acid solutions, specific gravity of      | 54       |
| —, limits in Pharmacopœia                        | 578, 581 |
| Arsenious oxide, solubility of                   | 127      |
| Atomic weights                                   | 1        |
| — —, multiples of                                | 3        |
| Azo compounds, formation of                      | 979      |
| Bacteriological examination of soils             | 806      |
| — — — water                                      | 624      |
| Barium acetate solutions, specific gravity of    | 55       |
| — bromide solutions, specific gravity of         | 54       |
| — chlorate, solubility of                        | 127      |
| — chloride solutions, specific gravity of        | 55       |
| — —, solubility of                               | 128      |
| — hydroxide, solubility of                       | 127      |
| — iodide solutions, specific gravity of          | 56       |
| Barometer readings, conversion of                | 1133     |
| — —, correction of                               | 171—3    |
| Baumé to specific gravity, conversion of degrees | 1135     |
| — — — —, — — — American degrees                  | 1136     |
| Beer, analysis of                                | 917      |
| — and spirits, alcohol content of                | 921      |
| Benzene and toluene mixtures                     | 967      |
| —, examination of                                | 973      |
| —, solubility of water in                        | 157      |
| Benzoic acid, determination of                   | 835, 850 |
| — —, solubility of                               | 129      |

|   | Page          |
|---|---------------|
| Benzol, examination of . . . . .                            | - 965         |
| —, ——— crude - . . . . .                                    | - 964         |
| —, <i>see</i> Benzene.                                      |               |
| Benzols, percentage composition of - . . . . .              | - 963         |
| —, properties of - . . . . .                                | - 962         |
| Blast furnace gas, analyses of - . . . . .                  | - 678         |
| Bleaching powder, valuation of - . . . . .                  | - 589         |
| Blood, examination of - . . . . .                           | 1046          |
| — in stains, recognition of - . . . . .                     | 1047          |
| Boiling points of elements - . . . . .                      | - 10          |
| — — — inorganic substances - . . . . .                      | - 263         |
| — — — organic compounds - . . . . .                         | - 335         |
| — — —, correction of, for pressure - . . . . .              | - 183         |
| Bomb calorimeter - . . . . .                                | 653           |
| Bone and Wheeler apparatus - . . . . .                      | - 616         |
| Borax bead tests - . . . . .                                | - 523         |
| — solutions, specific gravity of - . . . . .                | - 56          |
| —, solubility of - . . . . .                                | - 129         |
| —, valuation of - . . . . .                                 | - 587         |
| Boric acid, determination of - . . . . .                    | 833, 845      |
| — — solutions, specific gravity of - . . . . .              | - 56          |
| — —, solubility of - . . . . .                              | - 130         |
| Brandy containing 24.7 per cent. alcohol - . . . . .        | - 933         |
| —, secondary constituents of - . . . . .                    | - 925         |
| Brewing materials, analysis of - . . . . .                  | - 890         |
| —, measures used in - . . . . .                             | - 920         |
| British and American units, relation of - . . . . .         | 1127          |
| Bromine, solubility in water of - . . . . .                 | - 157         |
| Bunsen flame - . . . . .                                    | - 518         |
| Buoyancy corrections for sp. gr. determinations - . . . . . | - 28          |
| Burette readings, correction of - . . . . .                 | - 584         |
| Burning points of oils and tars - . . . . .                 | - 674         |
| Butter, analysis of - . . . . .                             | 840, 850      |
| Cadmium bromide solutions, specific gravity of - . . . . .  | - 57          |
| — chloride solutions, specific gravity of - . . . . .       | - 57          |
| — iodide solutions, specific gravity of - . . . . .         | - 57          |
| Calcium acetate solutions, specific gravity of - . . . . .  | - 58          |
| — bromide solutions, specific gravity of - . . . . .        | - 58          |
| — chloride solutions, density of - . . . . .                | - 58          |
| — —, solubility of - . . . . .                              | - 130         |
| — hydroxide, solubility of - . . . . .                      | - 131         |
| Calorimeter, bomb - . . . . .                               | - 654         |
| Cane sugar, analysis of - . . . . .                         | 854, 859, 881 |
| — — solutions, specific gravity of - . . . . .              | - 95          |
| — —, solubility of - . . . . .                              | - 131         |
| Capillary depression of mercury - . . . . .                 | - 173         |
| Caramel, analysis of - . . . . .                            | - 908         |
| Carbohydrates - . . . . .                                   | - 853         |
| Carbolic acid, examination of - . . . . .                   | - 969, 970    |

|   | Page       |
|---|------------|
| Carbon dioxide, density of                      | 109, 112   |
| — — —, estimation of                            | 608        |
| — — —, solubility in water                      | 120        |
| — monoxide, estimation of                       | 608        |
| Caustic potash solutions, density of            | 82         |
| — — — — —, partial pressure of                  | 180        |
| — — — — —, specific gravity of                  | 520        |
| — soda solutions, density of                    | 90         |
| — — — — —, specific gravity of                  | 528        |
| Cellulose, examination of                       | 946        |
| Cement, <i>see</i> Portland cement.             |            |
| Centigrade to Fahrenheit, conversion of degrees | 1129       |
| — — — Réaumur, conversion of degrees            | 1129       |
| Cheese, analysis of                             | 846, 851   |
| Chlorate, estimation of                         | 590, 593   |
| Chlorine, solubility in water                   | 121        |
| Chromate, estimation of                         | 593        |
| Chrome alum solutions, sp. gr. of ammonia       | 50         |
| — — — — — potassium                             | 80         |
| Chromic acid solutions, specific gravity of     | 59         |
| Chromium, estimation of                         | 593        |
| — sulphate solutions, specific gravity of       | 59         |
| Citric acid solutions, specific gravity of      | 59         |
| Clays, analysis of                              | 680        |
| Coal, analyses of                               | 663, 664   |
| — — —, analysis of                              | 661        |
| — — — gas, analysis of                          | 610        |
| — — —, properties of types of                   | 663, 664   |
| — — — tar                                       | 957        |
| — — — — —, yield on distillation                | 959        |
| — — — — — products, properties of               | 961        |
| — — — — —, examination of                       | 963        |
| — — — — —, treatment of                         | 958        |
| Cobalt ammonium sulphate, solubility of         | 132        |
| — chloride solutions, specific gravity of       | 60         |
| — sulphate, solubility of                       | 133        |
| Coke, analyses of bee-hive oven                 | 665        |
| — — — — — by-product                            | 666        |
| — — — oven gas, analyses of                     | 678        |
| Colouring matters in food products              | 851        |
| Combustion apparatus                            | 622        |
| Commercial names of intermediate products       | 977        |
| — — — — — drugs                                 | 1073, 1078 |
| Complex ions, formation of                      | 527        |
| Compressibility of gases, coefficients of       | 160        |
| Conductivity, thermal, of elements and alloys   | 13         |
| — — — — — gases                                 | 18         |
| Constant boiling mixtures                       | 185        |
| Conversion tables for weights and measures      | 1124       |



|  | Page         |
|--|--------------|
| Copper chloride solutions, specific gravity of | 60           |
| — nitrate solutions, specific gravity of       | 61           |
| — sulphate solutions, specific gravity of      | 61           |
| — —, solubility of                             | 134          |
| Cotton, analysis of fabrics containing         | 956          |
| Cream, analysis of                             | 839          |
| Creosote oil, examination of                   | 970          |
| — salts, examination of                        | 971          |
| Cresylic acid, examination of                  | 969          |
| Cryoscopic constants                           | 23           |
| Crystal systems, characteristics of            | 191          |
| Crystalline forms of inorganic substances      | 263, 200     |
| Crystallography                                | 189          |
| Cupric chloride solutions, specific gravity of | 60           |
| Densities, determination of                    | 25           |
| — of alloys                                    | 34           |
| — — gases                                      | 109, 112—116 |
| — — inorganic compounds                        | 262          |
| — — liquids, determination of                  | 25           |
| — — metals                                     | 33           |
| — — organic compounds                          | 334          |
| — — solids, determination of                   | 27           |
| — — solutions                                  | 37           |
| — — various substances                         | 36           |
| — — — woods                                    | 36           |
| Density, definition of                         | 24           |
| Dextrose solutions, density of                 | 62           |
| Diastatic activity                             | 895          |
| Diazo compounds, coupling of                   | 979          |
| Dilution table, universal                      | 108          |
| Dimethylaniline, examination of                | 975          |
| Drugs, trade names of                          | 1078         |
| Dry-way tests                                  | 500          |
| Dumas determination of nitrogen                | 624          |
| Du Pont nitrometer                             | 619          |
| Dyestuffs, composition of synthetic            | 980          |
| —, identification of                           | 1009         |
| —, preparation of                              | 980          |
| Ebonite, analysis of                           | 1097         |
| Ebullioscopic constants                        | 23           |
| Efficiencies of engines                        | 659          |
| Effluent analysis                              | 650          |
| Electrical resistance, specific                | 13           |
| Electro-chemical analysis                      | 628          |
| Electrolytic separations                       | 632          |
| Elements, boiling points of                    | 10           |
| —, electrical resistance of                    | 13           |
| —, latent heats of fusion of                   | 10           |
| —, latent heats of vaporisation of             | 10           |

|   | Page          |
|---|---------------|
| Elements, linear expansion of                   | 13            |
| —, melting points of                            | 10            |
| —, physical constants of                        | 10, 13        |
| —, specific heats of                            | 10            |
| —, thermal conductivities of                    | 13            |
| —, — constants of                               | 10            |
| Empirical formulæ of organic substances         | 334           |
| Essential oils                                  | 748           |
| — —, properties of                              | 760           |
| Ester value                                     | 724           |
| Ether, solubility of                            | 157           |
| — -alcohol mixtures, specific gravity of        | 48            |
| Expansion, coefficient of linear                | 13            |
| — of gases, coefficients of                     | 160           |
| Fahrenheit to Centigrade, conversion of degrees | 1130          |
| — — Réaumur, conversion of degrees              | 1130          |
| Fats, adulteration of                           | 725           |
| —, examination of                               | 719           |
| —, properties of                                | 734           |
| Feeding stuffs, analysis of                     | 815, 826      |
| — —, composition of                             | 816           |
| Fehling's solution                              | 573, 583      |
| Ferric chloride solutions, specific gravity of  | 62            |
| — nitrate solutions, specific gravity of        | 63            |
| — sulphate solutions, specific gravity of       | 63            |
| Ferrous ammonium sulphate solutions, sp. gr. of | 64            |
| — — —, solubility of                            | 135           |
| — sulphate solutions, specific gravity of       | 64            |
| — —, solubility of                              | 135           |
| Fertilisers, analyses of                        | 813           |
| Fire-bricks, analysis of                        | 680           |
| —, porosity of                                  | 686, 689      |
| —, refractoriness of                            | 687           |
| Fire-damp, analysis of                          | 612           |
| Flame spectra                                   | 634           |
| — tests   | 522           |
| Flash-point corrections for barometric pressure | 674           |
| — of oils and tars                              | 674           |
| Formaldehyde solutions, specific gravity of     | 65            |
| Formic acid solutions, density of               | 65            |
| Formula weights of radicals                     | 7             |
| — — — inorganic compounds                       | 262           |
| — — — organic compounds                         | 334           |
| Fuel gases, analysis of                         | 610           |
| — oils, calorific properties of                 | 673           |
| Fuels, calorific properties of                  | 656, 660, 672 |
| —, composition of liquid and solid              | 660, 672      |
| —, liquid, examination of                       | 649           |

|  | Page         |
|--|--------------|
| Fuming sulphuric acid, <i>see</i> Oleum.             |              |
| Furfural in spirits, determination of                | - 922        |
| Fusel oils, composition of                           | - 933        |
| Gas analysis   | - 604        |
| —, fuel, analysis of                                 | - 610        |
| —, liquefied, vapour pressures of                    | - 177        |
| — mixtures, analysis of                              | - 608        |
| — volumes, correction of                             | - 158        |
| —, — to N.T.P.                                       | - 161        |
| — volumetric analysis, tables for use in             | - 111        |
| Gaseous fuels, calorific value of                    | - 677, 679   |
| —, composition of                                    | - 677, 679   |
| Gases, absorbents for                                | - 608        |
| —, coefficients of expansion of                      | - 160        |
| —, densities of                                      | 112—116, 119 |
| —, physical properties of                            | - 18         |
| —, reactions of                                      | - 604        |
| —, solubilities of in alcohol                        | - 123        |
| —, — in water  | - 118        |
| —, specific heat of                                  | - 18         |
| —, thermal conductivities of                         | - 18         |
| —, viscosity of                                      | - 18         |
| —, weight of litre of various                        | - 112—116    |
| Glucose, analysis of                                 | - 869, 881   |
| Glycerin, analysis of                                | - 730        |
| — solutions, specific gravity of                     | - 66         |
| Grain, analysis of raw                               | - 904        |
| Group separations                                    | - 550        |
| —, notes on  | - 558        |
| Haldane apparatus                                    | - 614        |
| Heat of combustion                                   | - 658        |
| Hehner value   | - 723        |
| High-boiling aqueous solutions                       | - 188        |
| History of chemistry, notable dates in               | 1113         |
| Hops, analysis of                                    | - 910        |
| Hydriodic acid solutions, density of                 | - 66         |
| Hydrobromic acid solutions, specific gravity of      | - 67         |
| —, solubility in water of                            | - 121        |
| Hydrocellulose                                       | - 951        |
| Hydrochloric acid solutions, density of              | - 67         |
| —, change in density with temp.                      | - 68         |
| —, specific gravity of                               | - 709        |
| —, solubility in water of                            | - 121        |
| Hydrofluoric acid solutions, density of              | - 68         |
| Hydrofluosilicic acid solutions, specific gravity of | - 68         |
| Hydrogen, density of                                 | 110, 113     |
| — peroxide, tests for                                | - 531        |
| —, solubility in water of                            | - 119        |
| — sulphide, solubility in water of                   | - 122        |

|  | Page     |
|--|----------|
| Hydrometric tables                                 | 1134     |
| Hydrosulphite, valuation of                        | 594      |
| Ice cream, analysis of                             | 851      |
| Ignition temperatures of gaseous mixtures          | 679      |
| Illuminants  | 652      |
| Indiarubber, analysis of                           | 1086     |
| Indicators   | 586      |
| Inflammability of gas mixtures with air, limits of | 676      |
| Inorganic substances, properties of                | 262      |
| Insoluble substances, examination of               | 564      |
| Intermediate products                              | 973      |
| — — —, commercial names of                         | 977      |
| Invert sugar, analysis of                          | 868      |
| — — —, determination in cane sugar                 | 854      |
| Iodine solution, standard                          | 589      |
| — value  | 721      |
| Ions, reactions of                                 | 527      |
| Iron alum solutions, sp. gr. of ammonia            | 51       |
| — — — — —, — — — — — potassium                     | 83       |
| Iron, estimation of                                | 593      |
| Journals, volume and year                          | 1120     |
| Kjeldahl determination of nitrogen                 | 625      |
| Latent heats of fusion of compounds at M.Pt.       | 17       |
| — — — — — of elements at M.Pt.                     | 10       |
| — — — — — vaporisation of common liquids           | 16       |
| — — — — — elements at B.Pt.                        | 10       |
| Lead acetate solutions, specific gravity of        | 69       |
| — chloride, solubility of                          | 135      |
| —, limits allowed in Pharmacopœia                  | 578, 581 |
| — nitrate solutions, specific gravity of           | 69       |
| — — —, solubility of                               | 136      |
| Leather analysis                                   | 943      |
| —, analysis of vegetable tanned                    | 944      |
| —, — — — chrome                                    | 945      |
| Linear expansion, coefficient of                   | 13       |
| Linseed oil, analysis of                           | 787      |
| Lintner value                                      | 895      |
| Liquid fuels, burning points                       | 674      |
| — — —, examination of                              | 667      |
| — — —, flash points of                             | 674      |
| — — —, temperatures of spontaneous ignition        | 674      |
| Logarithms, five-figure                            | 1137     |
| Lunge nitrometer                                   | 618      |
| Magnesium bromide solutions, specific gravity of   | 70       |
| — chloride solutions, specific gravity of          | 70       |
| — iodide solutions, specific gravity of            | 70       |
| — sulphate solutions, density of                   | 71       |
| — — —, solubility of                               | 137      |
| Maize, analysis of                                 | 903      |

|   | Page       |
|---|------------|
| Malt analysis, commercial methods of . . . .              | - 893      |
| — extract, analysis of . . . . .                          | - 905      |
| — wort, analysis of . . . . .                             | - 912      |
| Manganese chloride solutions, specific gravity of . . . . | - 71       |
| — sulphate solutions, specific gravity of . . . . .       | - 71       |
| — —, solubility of . . . . .                              | - 137      |
| Manures, analysis of . . . . .                            | - 809, 824 |
| Mathematical constants . . . . .                          | 1159       |
| Maumené test . . . . .                                    | 723        |
| Mechanical constants . . . . .                            | 1165       |
| Medical prescriptions, signs used for . . . . .           | 1128       |
| — terms, glossary of . . . . .                            | 1085       |
| Melting points of elements . . . . .                      | - 10       |
| — — — inorganic substances . . . . .                      | - 263      |
| — — — — low m.pt. alloys . . . . .                        | - 14       |
| — — — — organic compounds . . . . .                       | - 335      |
| Mensuration formulæ . . . . .                             | 1164       |
| Mercuric chloride solutions, density of . . . . .         | - 72       |
| — —, solubility of . . . . .                              | - 138      |
| Mercury, capillary depression of . . . . .                | - 173      |
| —, density of . . . . .                                   | 31, 32     |
| Metallic deposits, removal of . . . . .                   | - 633      |
| — radicals, examination for . . . . .                     | - 548      |
| Metals, density of . . . . .                              | - 33       |
| Methyl alcohol solutions, density of . . . . .            | - 48       |
| Methylene blue, standard . . . . .                        | - 590      |
| Milk, adulteration of . . . . .                           | 836, 849   |
| —, analyses of . . . . .                                  | - 848      |
| —, analysis of . . . . .                                  | 827, 857   |
| —, — — — condensed . . . . .                              | - 838      |
| —, — — — dried . . . . .                                  | - 839      |
| —, — — — sterilized . . . . .                             | - 837      |
| —, specific gravity, correction for temp. . . . .         | - 827      |
| Minerals, colour of . . . . .                             | - 201      |
| —, composition of . . . . .                               | - 200      |
| —, crystalline structure of . . . . .                     | - 200      |
| —, fracture of . . . . .                                  | - 201      |
| —, fusibility of . . . . .                                | - 201      |
| —, hardness of . . . . .                                  | - 200      |
| —, lustre of . . . . .                                    | - 201      |
| —, solubility of . . . . .                                | - 201      |
| —, specific gravity of . . . . .                          | - 200      |
| —, streak of . . . . .                                    | - 201      |
| Molecular weights of inorganic compounds . . . . .        | - 262      |
| — — — organic compounds . . . . .                         | - 334      |
| Naphthalene, examination of . . . . .                     | - 971, 973 |
| — sulphonic acids, commercial names of . . . . .          | - 960      |
| Naphthas, properties of . . . . .                         | - 962      |
| —, examination of . . . . .                               | - 965      |

|  | Page       |
|--|------------|
| Naphthionic acid, solubility of              | - 138      |
| Natural gas, analyses of                     | - 679      |
| — — —, calorific value of                    | - 679      |
| Nessler solution                             | - 573      |
| Nickel ammonium sulphate, solubility of      | - 139      |
| — chloride solutions, specific gravity of    | - 72       |
| — — —, solubility of                         | - 138      |
| — sulphate solutions, density of             | - 72       |
| — — —, solubility of                         | - 139      |
| Nicotine, estimation of                      | 1104       |
| Nitrates, estimation of                      | - 586      |
| Nitric acid solutions, density of            | - 73       |
| — — — —, change in density with temp.        | - 75       |
| — — — —, influence of $N_2O_4$ on density of | - 75       |
| — — — —, specific gravity of                 | - 707      |
| — — — —, change in sp. gr. with temp.        | - 708      |
| Nitrobenzene, solubility in water of         | - 157      |
| Nitrogen, density of                         | - 116      |
| —, Dumas' method for determination of        | - 624      |
| —, Kjeldahl method for determination of      | - 625      |
| —, solubility in water                       | - 119      |
| Nitrometer                                   | - 618, 619 |
| Normal solutions                             | - 585      |
| N.T.P., correction to                        | - 161      |
| Oils, viscosities of                         | - 21       |
| Oils and fats, constants of                  | - 721      |
| — — — —, examination of                      | - 719      |
| —, fats and waxes, properties of             | - 734      |
| Oleum, analysis of                           | - 703      |
| —, boiling point of                          | - 705      |
| —, dilution of                               | - 706      |
| —, percentage $SO_3$ in                      | - 704      |
| —, solidifying point of                      | - 706      |
| —, specific gravity of                       | - 103      |
| Organic compounds, properties of             | - 334      |
| — — —, nomenclature of                       | - 330      |
| — — —, ultimate analysis of                  | - 621      |
| Orsat apparatus                              | - 612      |
| Oxalic acid solutions, specific gravity of   | - 75       |
| — — —, solubility of                         | - 139      |
| Oxycellulose                                 | - 951      |
| Oxygen, density of                           | - 114      |
| —, solubility in alcohol                     | - 122      |
| —, — — — water                               | - 118, 119 |
| Ozone, tests for                             | - 531      |
| Paint materials, analysis of                 | - 787      |
| Paints, analysis of                          | - 791      |
| Paper, examination of                        | - 946      |
| Partial pressure of aqueous vapour           | - 180      |
| Patents, chemical invention and the Law of   | 1108       |
| Pentoses and pentosans, determination of     | - 884      |

|  | Page     |
|--|----------|
| Periodic system                                  | 8        |
| Permanganate, standard                           | 587      |
| Petroleum, calorific properties of               | 673      |
| Pharmaceutical names of synthetic compounds      | 1073     |
| Phenol, <i>see</i> Carbohic acid.                |          |
| —, solubility in water of                        | 157      |
| Phosphoric acid solutions, specific gravity of   | 76       |
| Physical properties of gases                     | 18       |
| Physiological chemistry                          | 1030     |
| Pigments, analysis of                            | 776      |
| Pitch, examination of                            | 971      |
| Platinichlorides, solubility of                  | 140      |
| Polenské number                                  | 842      |
| Porosity of refractory materials                 | 686, 689 |
| Portland cement, analysis of                     | 622      |
| —, composition of various                        | 697, 698 |
| —, standard specification of                     | 694, 695 |
| Potash alum solutions, specific gravity of       | 76       |
| —, solubility of                                 | 140      |
| Potassium acetate solutions, specific gravity of | 77       |
| —, solubility of                                 | 140      |
| Potassium acetate solutions, specific gravity of | 77       |
| —, solubility of                                 | 141      |
| — antimonyl tartrate, solubility of              | 141      |
| — bichromate, <i>see</i> dichromate.             |          |
| — bisulphide solutions, specific gravity of      | 77       |
| — bitartrate, solubility of                      | 141      |
| —, valuation of                                  | 587      |
| — bromate solutions, specific gravity of         | 78       |
| — bromide solutions, density of                  | 79       |
| —, solubility of                                 | 141      |
| — carbonate solutions, specific gravity of       | 78       |
| —, solubility of                                 | 142      |
| — chlorate solutions, specific gravity of        | 79       |
| —, solubility of                                 | 143      |
| — chloride solutions, density of                 | 79       |
| —, solubility of                                 | 143      |
| —, solubility in magnesium chloride solutions    | 144      |
| — — sodium chloride, solubility of               | 143      |
| — chromate solutions, specific gravity of        | 80       |
| —, solubility of                                 | 145      |
| — chrome alum solutions, specific gravity of     | 80       |
| — dichromate solutions, specific gravity of      | 81       |
| —, solubility of                                 | 145      |
| —, standard                                      | 587      |
| — ferricyanide solutions, specific gravity of    | 81       |
| —, solubility of                                 | 146      |
| — ferrocyanide solutions, specific gravity of    | 81       |
| —, solubility of                                 | 146      |
| —, standard                                      | 595      |



|  | Page       |
|--|------------|
| Potassium hydroxide solutions, density of              | 82         |
| — — —, specific gravity of                             | 715        |
| — — —, solubility of                                   | 146        |
| — iodate solutions, specific gravity of                | 82         |
| — — —, solubility of                                   | 149        |
| — iodide solutions, density of                         | 83         |
| — — —, solubility of                                   | 147        |
| — iron alum solutions, specific gravity of             | 83         |
| — nitrate solutions, specific gravity of               | 83         |
| — — —, solubility of                                   | 148        |
| — — — -sodium nitrate, solubility of                   | 148        |
| — oxalate, acid, solutions, specific gravity of        | 84         |
| — — —, — — —, solubility of                            | 149        |
| — — — solutions, specific gravity of                   | 84         |
| — perchlorate, solubility of                           | 143        |
| — permanganate, standard                               | 587        |
| — sulphate solutions, specific gravity of              | 84         |
| — — —, solubility of                                   | 149        |
| Potassium sulphide solutions, density of               | 85         |
| — tartrate solutions, specific gravity of              | 85         |
| — thiocyanate, solubility of                           | 149        |
| Powers of numbers                                      | 1160       |
| Preservatives in butter                                | 844, 850   |
| Proof spirit   | 928        |
| — — —, conversion of sp. gr. to degrees of             | 928        |
| Pyknometer   | 25         |
| Pyridine, examination of commercial                    | 969        |
| Pyrites, valuation of                                  | 700        |
| Qualitative analysis                                   | 518        |
| Quantitative analysis, factors for                     | 596        |
| Quevenne degrees                                       | 848        |
| Radicals, formula weights of                           | 7          |
| Rare gases, solubilities in water                      | 120        |
| Rarer metals, reactions of                             | 567        |
| Reagents   | 572        |
| — — —, impurities in                                   | 574        |
| Réaumur degrees  | 1129, 1130 |
| Refractive indices                                     | 22         |
| Refractoriness of fire-bricks                          | 687, 691   |
| Refractory materials, porosity of                      | 686, 689   |
| Reichert-Polenske process                              | 842        |
| Resistance, specific electrical                        | 13         |
| Rice, analysis of                                      | 903        |
| Rochelle salt solutions, specific gravity of           | 85         |
| Rubber, <i>see</i> Indiarubber.                        |            |
| Rums, analyses of                                      | 927        |
| Saccharometer readings, conversion to specific gravity | 874        |
| — — —, correction of                                   | 879        |
| Salicylic acid, solubility of                          | 129        |

|   | Page   |
|---|--------|
| Saponification value                          | 721    |
| Sewage analysis                               | 650    |
| Silica materials, porosity of                 | 690    |
| Silk, analysis of fabrics containing          | 956    |
| Silver chloride, solubility in salt solutions | 150    |
| — nitrate solutions, specific gravity of      | 85     |
| — —, solubility of                            | 150    |
| — —, standard                                 | 594    |
| Sines, natural                                | 1162   |
| Soap analysis                                 | 726    |
| — lyes, glycerin in                           | 733    |
| Soda ash, valuation of                        | 713    |
| Sodium acetate solutions, specific gravity of | 86     |
| — —, solubility of                            | 150    |
| — arsenate solutions, specific gravity of     | 86     |
| — — —, — — — acid                             | 87     |
| — bicarbonate, solubility of                  | 151    |
| — — — in sodium chloride solutions            | 152    |
| — bichromate, <i>see</i> dichromate.          |        |
| — bromate solutions, specific gravity of      | 87     |
| — —, solubility of                            | 151    |
| — bromide solutions, density of               | 88     |
| — —, solubility of                            | 151    |
| — carbonate solutions, specific gravity of    | 88     |
| — — —, change in sp. gr. of, with temp.       | 88     |
| — —, solubility of                            | 152    |
| — — —, in sodium chloride solutions           | 152    |
| — chlorate solutions, specific gravity of     | 89     |
| — —, solubility of                            | 151    |
| — chloride solutions, specific gravity of     | 89     |
| — —, solubility of                            | 153    |
| — — — potassium chloride, solubility of       | 143    |
| — — — — in magnesium chloride solutions       | 144    |
| — chromate, solubility of                     | 153    |
| — dichromate, solubility of                   | 153    |
| — ferrocyanide, solubility of                 | 154    |
| — hydroxide solutions, density of             | 90     |
| — — —, change in density with temp.           | 90     |
| — — —, specific gravity of                    | 713    |
| — —, solubility of                            | 154    |
| — iodate solutions, specific gravity of       | 90     |
| — —, solubility of                            | 151    |
| — iodide solutions, density of                | 91     |
| — —, solubility of                            | 154    |
| — nitrate solutions, density of               | 91     |
| — —, solubility of                            | 155    |
| — — — potassium nitrate, solubility of        | 148    |
| — phosphate solutions, specific gravity of    | 91, 92 |
| — —, solubility of                            | 155    |

|   | Page          |
|---|---------------|
| Sodium sulphate solutions, specific gravity of  | 92            |
| — —, solubility of                              | 156           |
| — sulphide solutions, density of                | 93            |
| — —, standard                                   | 595           |
| — sulphite solutions, specific gravity of       | 93            |
| — —, solubility of                              | 156           |
| — tartrate solutions, density of                | 94            |
| — thiosulphate solutions, specific gravity of   | 93            |
| — —, standard                                   | 589           |
| — tungstate solutions, specific gravity of      | 94            |
| Soil analysis                                   | 798, 818      |
| Soils, analyses of typical                      | 809, 823      |
| Solubilities of gases in liquids                | 117           |
| — — gases in alcohol                            | 123           |
| — — inorganic substances                        | 201           |
| — — liquids in liquids                          | 157           |
| — — organic compounds                           | 335           |
| — — solids in liquids                           | 124           |
| Soluble starch, preparation of                  | 896           |
| Solution analysis                               | 527           |
| Spark spectra                                   | 635           |
| Specific gravities, conversion to densities     | 29            |
| — —, definition of                              | 24            |
| — — determination of                            | 25            |
| — —, buoyancy corrections                       | 28            |
| — — of alloys                                   | 34            |
| — — solids, determination of                    | 27            |
| — — solutions                                   | 37            |
| — heat of elements                              | 10            |
| — — gases                                       | 18            |
| — — liquids                                     | 16            |
| — — miscellaneous substances                    | 17            |
| — — water                                       | 15            |
| Spectrum analysis                               | 634           |
| Spirits, alcohol content of                     | 921           |
| —, analysis of                                  | 922           |
| Spontaneous ignition, temperatures of           | 674           |
| Standard solutions                              | 584           |
| Stannic chloride solutions, specific gravity of | 105           |
| Stannous chloride, estimation of                | 593           |
| Starch, determination of                        | 885           |
| —, soluble, preparation of                      | 896           |
| — sugar, analysis of                            | 869, 883      |
| —, water content of                             | 885, 886      |
| Sucrose solutions, percentage content of        | 860           |
| — —, viscosities of                             | 20            |
| Sugar, gravimetric determination of             | 854, 859, 881 |
| —, solubility of cane                           | 131           |

|  |          |
|--|----------|
|  | Page     |
| Sugar solutions, specific gravity of cane -          | 95       |
| — —, change in sp. gr. of, with temp. -              | 96       |
| —, volumetric determination of -                     | 880      |
| Sugars, analysis of commercial -                     | 871      |
| —, behaviour towards certain reagents -              | 853      |
| —, specific rotatory powers of -                     | 872      |
| Sulphite, determination of -                         | 590      |
| Sulphonic acids, commercial names of -               | 978      |
| Sulphur solutions in carbon disulphide, sp. gr. of - | 699      |
| —, valuation of -                                    | 699      |
| — dioxide, solubility in water of -                  | 122      |
| Sulphuric acid, boiling point of -                   | 705      |
| — —, concentrated, boiling point of -                | 760      |
| — —, concentrated, density and sp. gr. of -          | 536      |
| — —, dilution table for -                            | 101      |
| — —, fuming, <i>see</i> Oleum.                       |          |
| — —, hydrometer correction table for -               | 99       |
| — —, solidifying point of -                          | 706      |
| — — solutions, density of -                          | 97       |
| — — —, specific gravity of -                         | 97, 701  |
| — — —, vapour pressure of -                          | 179, 180 |
| Tangents, natural -                                  | 1162     |
| Tannic acid solutions, specific gravity of -         | 104      |
| Tannin analysis, official method -                   | 939      |
| — —, — American method -                             | 940      |
| —, estimation of -                                   | 938      |
| — materials, qualitative examination of -            | 934      |
| — —, identification of -                             | 936      |
| — —, reactions of -                                  | 937      |
| —, percentage in tannin materials -                  | 942      |
| Tar, <i>see</i> Coal tar.                            |          |
| Tars, calorific properties of -                      | 673      |
| Tartar emetic solutions, specific gravity of -       | 104      |
| — —, solubility of -                                 | 141      |
| Tartaric acid solutions, specific gravity of -       | 104      |
| Textile fibres, examination of -                     | 955      |
| Thermal conductivity of alloys -                     | 13       |
| — — — elements -                                     | 13       |
| — — — gases -  | 18       |
| — — — miscellaneous substances -                     | 17       |
| — constants of elements -                            | 10       |
| Thermometer readings, correction of -                | 181, 182 |
| — scales -   | 1129     |
| Thiocyanate, standard -                              | 594      |
| Titanous chloride, standard -                        | 590      |
| Tobacco -  | 1103     |
| —, composition of American -                         | 1107     |
| —, excise regulations -                              | 1103     |
| —, technical assay of -                              | 1103     |

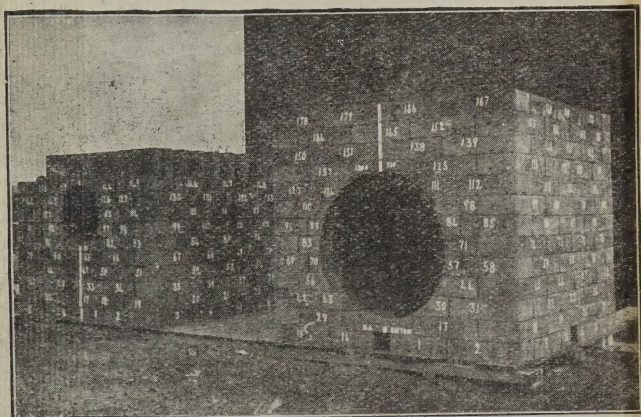
|  | Page      |
|--|-----------|
| Toluene and benzene mixtures                     | 967       |
| — — xylene mixtures                              | 968       |
| —, examination of                                | 973       |
| —, percentage in commercial toluol               | 966       |
| Toluidines, specific gravity of mixtures of      | 976       |
| Toluol, percentage of toluene in commercial      | 965, 966  |
| —, examination of                                | 966       |
| Trade names                                      | 977, 1078 |
| Trigonometrical formulæ                          | 1164      |
| Turpentine, analysis of                          | 789       |
| Twaddell degrees, conversion to specific gravity | 1134      |
| Ultimate analysis of organic substances          | 621       |
| Urine, examination of                            | 1030      |
| Vapour pressures                                 | 173       |
| — — of liquefied gases                           | 177       |
| Viscosities of alcohol-water mixtures            | 20        |
| — — gases  | 18        |
| — — liquids                                      | 21        |
| — — oils   | 21        |
| — — sucrose solutions                            | 20        |
| Viscosity of water                               | 20        |
| Volumetric analysis                              | 584       |
| Water analysis                                   | 638       |
| —, bacteriological examination of                | 644       |
| —, boiling point at different pressures          | 184       |
| —, density of                                    | 30, 31    |
| — for use in brewing                             | 890, 891  |
| — glass, total alkali in                         | 586       |
| —, specific heat of                              | 15        |
| — treatment, factors for                         | 890       |
| —, substances used in                            | 892       |
| —, vapour pressure of                            | 173, 174  |
| —, viscosity of                                  | 20        |
| Waxes, properties of                             | 734       |
| Weights and measures, conversion tables          | 1124      |
| Whisky, secondary constituents of                | 926       |
| Wool, analysis of fabrics containing             | 956       |
| Wort, analysis of malt wort                      | 913       |
| —, strength corresponding to spirit indication   | 921       |
| X rays and crystals                              | 199       |
| Xylene and toluene mixtures                      | 968       |
| Zinc bromide solutions, specific gravity of      | 105       |
| — chloride solutions, specific gravity of        | 106       |
| — iodide solutions, specific gravity of          | 106       |
| — nitrate solutions, specific gravity of         | 107       |
| — sulphate solutions, specific gravity of        | 107       |



# DOUBLE THE LIFE AND INCREASE THE EFFICIENCY

of your Acid Towers by lining and  
packing with **ACID & FIRE-PROOF**

# **OBSIDIANITE** (REGD.)



Photograph of Entablatures of a Glover Tower and a Gay-Lussac Tower  
made for the Government of India.

## **OBSIDIANITE ACID-PROOF**

Arches, Grids and Ring Packing for Glover Towers.  
Every block fitted and numbered for re-erection.

**Important parts always kept in stock for immediate  
despatch.**

Tel. Address: "DAVISON, BUCKLEY."

Telephone No. 4, BUCKLEY.

**CHARLES DAVISON & CO., LTD.,**

*Fire and Acid Brick Specialists,*

**Ewloe Barn, Buckley, Chester.**

UNIVERSITY OF ILLINOIS-URBANA



3 0112 058665792